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APR 77 C L RONE, A L SULLIVAN

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MEMBRANE ENCAPSULATED SOIL LAYER (MESL) FOR CONTINGENCY AIRFIELDS

U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION
SOILS AND PAVEMENTS LABORATORY
P. O. BOX 631 VICKSBURG, MISSISSIPPI 39180

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(AIR FORCE SYSTEMS COMMAND)
TYNDALL AIR FORCE BASE
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This study was conducted to evaluate thickness requirements for membrane encapsulated soil layers (MESL) having various surfacing materials when subjected to 100 passes of F-4C aircraft loading and to determine the feasibility of constructing thin layers (5 to 9 inches) of MESL on low strength subgrade. A test section consisting of five items was constructed and trafficked. All five items were constructed on a prepared subgrade having a rated

(continued)

20. ABSTRACT (concluded)

California Bearing Ratio (CBR) of 7. Thicknesses of MESL base courses were 9, 5, 7, 9, and 9 inches for items 1 through 5, respectively. Surfacing material consisted of 4 inches of asphaltic concrete on items 1 and 2, 2 inches of asphaltic concrete on item 3, only the waterproof surfacing of the MESL on item 4, a synthetic turf on item 4A, and a 1-1/2-inch-thick sod on item 5. The significant findings of this study are that (1) thin MESL base courses can be constructed over a 7 CBR subgrade; (2) a MESL with only the waterproof surface will structurally withstand 10 coverages of F-4C traffic but may be rendered susceptible to water due to wrinkling of the waterproof surfacing under traffic; (3) a MESL is susceptible to infiltration of water when overlaid with a layer of wet material such as sod; and (4) a MESL base course 7 inches thick with a 2-inch surfacing of asphalt concrete constructed on a 7 CBR subgrade will withstand 14 coverages (approximately 140 passes) of F-4C traffic.

PREFACE

This investigation was conducted by the U. S. Army Engineer Waterways Experiment Station (WES) for the U. S. Air Force Civil and Environmental Engineering Development Office (CEEDO) as part of the Contingency Launch and Recovery Program, under program element 6.4708F. The investigation reported herein was authorized by Project Order No. 76-037 dated 27 April 1976. The investigation was conducted between May 1976 and February 1977 by personnel of the Soils and Pavements Laboratory. Mr. Donald N. Brown (CEEDO/CNO) was project officer.

This report has been reviewed by the information office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
mils	0.0254	millimetres
inches	2.54	centimetres
feet	0.3048	metres
square yards	0.8361273	square metres
gallons (U. S. liquid)	3.785412	cubic decimetres
pounds	0.45359237	kilograms
tons	0.90718474	metric tons
pounds per square inch	0.6894757	newtons per square centimetre
pounds per cubic foot	16.018489	kilograms per cubic metre
Fahrenheit degrees	5/9	Celsius or Kelvin degrees*

* To obtain Celsius (C) temperature readings Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

SECTION I
INTRODUCTION

BACKGROUND

Modern aircraft's dependency on high-quality operating facilities has made the facilities an extremely vulnerable target for enemy attack. The need, therefore, exists to have contingency facilities adjacent to, or in the vicinity of, existing facilities that are capable of supporting a limited number of launchings and recoveries of aircraft in the event main facilities are damaged by enemy attack.

To justify contingency-type facilities, the most economical materials and methods should be used in design and construction. One method of constructing this type facility is to use membrane encapsulated soil layers (MESL) as described in Reference 1. This method of construction has the economical advantage of using soil existing at a site and compacting it at a water content of 2 to 4 percent below optimum to obtain greater strength, then encapsulating the compacted material in a waterproof envelope to maintain the required water content and high strength when exposed to natural environmental conditions.

OBJECTIVES

The primary objectives of this investigation were to determine thickness requirements of MESL having various surfacing materials to support 100 passes (approximately 10 coverages) of aircraft having a 25,000-pound[1] single-wheel load and a tire pressure of 250 psi and to determine the feasibility of constructing thin layers of MESL using fine-grained soil over low strength subgrade material. The objectives were accomplished by:

1. Constructing a test section having a uniform strength subgrade and varying thicknesses of MESL and surfacing material.

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[1] A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented in front matter of this report.

2. Surfacing three items with asphaltic concrete, one item with Bermuda grass sod, part of an item with synthetic turf, and one item with the bare MESL as a surface.

3. Subjecting the test section to simulated F-4C aircraft traffic loading using a 25,000-pound single-wheel load on a 30 by 11.5, 24 ply rating aircraft tire inflated to 250 psi.

4. Observing the behavior of the test section under traffic.

5. Performing as-constructed and after-traffic soils tests to determine performance and changes in strength of both MESL base and subgrade.

This report contains a description of the materials used in the test section, construction techniques, tests conducted and results, and an analysis of the performance.

SECTION II

MATERIALS, DESIGN, AND CONSTRUCTION

SOILS

Classification data for the soils used in construction of the test section are shown in Figure 1. Soil 1, a heavy clay (CH) with an average liquid limit of 73 and plasticity index of 48, was used for the prepared subgrade. This material was imported from an alluvial backswamp deposit along the Mississippi River. Soil 2, a lean clay (CL) material with an average liquid limit of 34 and plasticity index of 12, was used for the MESL base course. The lean clay was obtained from the residual loess deposits on the WES reservation.

As-molded laboratory compaction and California Bearing Ratio (CBR) data for the heavy clay are shown in Figure 2. The data in the lower left graph indicate the relation between molding water content and dry density, and the data in the upper left graph indicate the relation between molding water content and CBR. The graphs to the right, density versus CBR, and molding water content versus CBR were derived from the first two relations. Data presented in Figure 2 were used to determine the moisture-density relation for construction of the subgrade in the test section to obtain the required in-place CBR. Laboratory compaction and CBR data for the lean clay are shown in Figures 3 and 4. The data in Figure 3 are for the as-molded condition, and the data in Figure 4 were obtained after the molded specimens had been subjected to a 4-day soaking period. These two conditions are similar to "as-constructed" and "saturated" field conditions. Data presented in Figure 3 were used to determine the moisture density relation for construction of the MESL to obtain the in-place CBR necessary to support the specified load. Data presented in Figure 4 show the effect an increase in water content would have on the strength of the MESL.

MEMBRANES

Membranes used to encapsulate the lean clay base course were 6-mil nontransparent polyethylene and Petromat polypropylene. The polyethylene was used on the bottom and sides of the MESL. The Petromat polypropylene was used

on the surface of the MESL and is a nonwoven fabric produced from petroleum-based products similar in appearance to light felt. Physical properties and descriptions of the materials are given in Reference 2.

ASPHALTIC CONCRETE

Asphaltic concrete for surfacing on items 1, 2, and 3 was obtained from, and placed by, a local contractor. The mixture was produced to local highway specifications for surface course mixtures. Aggregate used in the mixture was a crushed gravel blended with sand that produced a mixture gradation as shown in Figure 5. Specification limits shown in Figure 5 are for 1/2-inch-maximum-size aggregate surface course mixture for high pressure tires as given in TM 5-822-8, "Bituminous Pavements Standard Practice." Laboratory data obtained from samples of the material taken during placing are shown in Table 1.

LOCATION OF THE SECTION

The test section was located on the WES reservation under an open-end shelter to control moisture during construction and trafficking. To obtain sunlight, the sod item was located near an open end.

DESIGN

A plan and profile of the test section are shown in Figure 6. The test section was 25 feet wide consisting of five test items with dimensions as shown in the figure. Item 4A was included after construction of the initial five items. The subgrade for all items was a heavy clay (CH), and the MESL base course was constructed of lean clay (CL).

The total thickness of MESL and surfacing material above the prepared subgrade was determined in accordance with criteria developed and presented in Reference 3. A design thickness of 9 inches of MESL and surfacing material was determined after in-place tests on the as-constructed subgrade indicated that the subgrade would develop a rated CBR of about 7. This 9-inch total thickness was used for items 2, 3, 4, and 5, and the thickness of item 1 was increased 4 inches to a total of 13 inches. This was done to insure adequate strength in the MESL since thin MESL's had not been previously constructed over low

strength subgrades. The 13-inch thickness was also utilized in order to insure that at least one of the items would withstand the number of passes required by the sponsor.

Surfacing material for items 1 and 2 was 4 inches of hot-mix asphaltic concrete, and for item 3 was 2 inches of asphaltic concrete. Item 4 was a bare MESL surface, and item 5 was a MESL with approximately 1-1/2 inches of sod on the surface. A 12-foot section between items 4 and 5 was surfaced with a synthetic turf placed directly on the surface of the MESL and referred to hereafter as item 4A.

The thicknesses of MESL for items 1 through 5 were 9, 5, 7, 9, and 9 inches, respectively. Based on criteria presented in Reference 4, an in-place CBR of at least 18 is required to support a 25,000-pound wheel load at 250 psi tire pressure on unsurfaced soils for 10 coverages (96 passes); therefore, the design was based on obtaining a CBR of at least 18 on the surface of the lean clay in the MESL. Laboratory data indicate that the lean clay would produce a CBR of at least 30 when compacted to a density of 105 lb/cu ft at a water content of 15 percent.

CONSTRUCTION

An area 200 feet long and 25 feet wide was excavated to an average depth of 30 inches (Figure 7). The bottom of the excavation was processed to a 6-inch depth and a moisture content of about 28 percent. The excavated heavy clay was transported to a special stockpile area and processed for use in the construction of the subgrade. The heavy clay subgrade was constructed in three compacted lifts, each approximately 7 inches thick, to form a uniformly compacted subgrade thickness of approximately 27 inches. The material for each lift was processed to a water content of about 27 percent, then transported to the test site by dump truck and end dumped into the excavation. The loose material was spread evenly with a D-4 tractor (Figure 8) and compacted with eight coverages of a 50-ton towed-type, rubber-tired roller having four tires, each inflated to 90 psi.

CBR, moisture content, and density determinations were made as each subsequent lift was compacted (Figure 9). The average as-constructed water content of the subgrade was 26.9 percent at a dry density of 90.4 lb/cu ft, which resulted in an average CBR in the top 12 inches of the subgrade of 6.4.

The subgrade was cut to finished grade with a motor grader (Figure 10). Item 1 was cut approximately 4 inches lower than items 2 through 5 (see profile, Figure 6) to allow for the thicker MESL.

The finished subgrade was covered with a 6-mil thick polyethylene membrane that extended beyond the sides of the excavation enough to overlap the top of the compacted lean clay about 2 feet (Figure 11). This membrane served as the waterproofing skin for the bottom and sides of the MESL. The lean clay soil used in the encapsulated layer was transported from the borrow area to the special processing site where the material was processed to a water content of about 15 percent. The processed material was transported by dump truck and end dumped upon the polyethylene-covered subgrade (Figure 12). The loose soil was spread evenly with a D-4 tractor (Figure 13) to a minimum thickness of 12 inches to prevent rupturing the polyethylene membrane and to insure that adequate thickness was present for compaction of the lean clay soil over the low strength subgrade. Compaction was attained by applying eight coverages of a 50-ton towed roller having four tires each inflated to 90 psi (Figure 14) and then eight additional coverages at 110 psi tire pressure for a total of 16 coverages. Hairline cracks began developing in the lean clay (Figure 15) due to deflection, and compaction was terminated. CBR, water content, and density determinations were made after compaction, and the average as-constructed water content of the lean clay layer was 15.8 percent at a dry density of 98.9 lb/cu ft, which resulted in an initial CBR of 22. Data for each item are shown in Table 2.

A motor grader was used to cut the compacted lean clay to a thickness of 9 inches in items 1, 4, and 5; 5 inches in item 2; and 7 inches in item 3 (Figure 16).

The edges of the section were sprayed with RS-2C asphalt emulsion to tack down the edges of the overlapping lower membrane (Figure 17). The installation of the upper membrane was accomplished with an asphalt distributor truck for spraying the RS-2C emulsion with an attached laying yoke for unrolling the porous polypropylene membrane (Figure 18). Twelve-foot widths of polypropylene were used on each side of the test section, and a 15-foot-wide roll was used down the center and overlapping the side strips. The asphalt emulsion was applied at a temperature of 140°F, with an application of 0.45 gal/sq yd on the surface of the lean clay, then an additional

0.25 gal/sq yd was applied to the surface of the polypropylene. A blotter course of limestone dust was sifted with shovels over the treated surface and brushed evenly with brooms. The surface of the MESL was rolled with a 30-ton self-propelled, rubber-tired roller to seal the polypropylene to the compacted lean clay (Figure 19).

The asphaltic concrete on items 1, 2, and 3 was placed with a conventional asphalt spreader in two lanes. One lane was 11.5 feet wide, and the other was 12.5 feet wide for a total width of 24 feet. Two inches of material was placed and compacted on items 1, 2, and 3, then the second 2 inches was placed on items 1 and 2. The width of lanes was reversed on the second lift in order to offset the joint in the layers. The asphaltic concrete was placed at a temperature of 270°F, and compaction began at a temperature of 240°F. Breakdown rolling was accomplished with a 23,500-pound dual-drum steel-wheel roller (Figure 20) and compaction with 18 coverages of a 38,500-pound 11-wheel pneumatic-tired roller (Figure 21) at a tire pressure of 90 psi. When compaction with the pneumatic-tired roller was completed, four coverages of finish rolling were applied with the steel-wheel roller. Results of laboratory and in-place tests on the finished asphaltic concrete are shown in Table 1.

Item 5 was surfaced with Bermuda grass sod (Figure 22), placed by hand in 1- by 2-foot lengths. The voids between the sod pieces were filled with sand, then the item was rolled with a 30-ton self-propelled, rubber-tired roller at a tire pressure of 30 psi (Figure 23). The sod overlay was watered daily to facilitate growth and the intertwining of the roots.

Surfacing on item 4A consisted of a 12-foot-wide by 25-foot-long section of synthetic turf placed in a transverse direction over the MESL. The synthetic turf was adhered to the surface with a tack coat of RS-2C asphalt emulsion.

After completion of construction, a 10-foot-wide traffic lane was laid out in the center of the section, and traffic pattern guide lines were painted on items 1 through 4A, and stringline guides were used for item 5. Figure 24 shows the surface of the completed test section.

SECTION III

TESTING AND BEHAVIOR UNDER TRAFFIC

TRAFFIC PATTERN

Traffic was applied to the test section using the vehicle shown in Figure 25. To apply the test traffic, the vehicle was driven forward and backward along the same path, then shifted laterally a distance equal to one tire width and the process repeated. Therefore, when the test vehicle had transversed the full distance across the test lane, a total of two coverages of traffic had been applied over the test lane. Traffic was applied in an approximately normal distribution pattern as shown in Figure 26. The interior 60 inches of the traffic lane received 100 percent of the applied traffic, and the exterior portion of the lane received 80 and 20 percent as shown. This pattern is similar to the distribution occurring on runways during actual aircraft operations. Coverages referred to herein are the number of coverages in the 100-percent zone. Using this traffic pattern, 10 coverages in the 100-percent zone are equal to 96 passes of aircraft in the 10-foot-wide distribution pattern shown in Figure 26.

SOIL TESTS AND OBSERVATIONS

In-place CBR, water content, and dry density tests were conducted on each item on the subgrade and MESL base course during construction and after traffic. Results of these tests are presented in Table 2. A minimum of three determinations was made at each increment of depth indicated, and the values in Table 2 corresponding to the various depths are averages of the values ascertained at that particular depth. Level readings were taken on each item on the surface of the subgrade, MESL, and surfacing materials during construction, and on the surfacing material at various intervals of traffic. These data are shown in Figure 27. After traffic was terminated, level readings were taken on the surface, trenches were excavated across the traffic lane and level readings taken on the surface of MESL and subgrade in each item. Results are shown in Figure 27. Prior to traffic and at intervals during traffic, static deflections were taken at the center of items 1, 2, 3, and 4. A rolling wheel drawbar pull was determined along the centerline

of the test section prior to trafficking. Visual observations of construction and behavior under traffic were recorded and supplemented with photographs.

FAILURE CRITERIA

In judging the failure of the items surfaced with asphaltic concrete (items 1, 2, and 3), one or more of the following conditions had to be met before an item was considered failed:

1. Surface upheaval of the pavement adjacent to the traffic lane of 1 inch or more must develop.

2. Cracking must extend completely through the asphaltic concrete and the membrane surfacing of the MESL base course to such an extent that the MESL base course would no longer be waterproof.

Failure criteria established for the unsurfaced MESL, the artificial turf, and the sod surface were as follows:

1. The MESL and surfacing no longer waterproof.

2. Single ruts 3 or more inches deep.

3. Deformation across the traffic lane combined with upheaval at the edge of traffic lane 3 inches or more.

DRAWBAR PULL MEASUREMENTS

Rolling-wheel drawbar pulls were made along the centerline of the test section before traffic was applied. The load cart was towed by a prime mover and the force measured by a pressure cell connected to the towing cable. Figure 28 shows the arrangement and recording of load readings. The load cart was stopped on each item for 2 minutes then started, except in item 2 where it was stopped for approximately 10 minutes for photographs. Table 3 shows the force required to start the cart and the average force required to keep the cart rolling along the section. The force required to start the load cart in item 5 was not obtained because the item failed, but a rolling force was recorded prior to stopping the test.

BEHAVIOR UNDER TRAFFIC

ITEM 1

Figure 29 shows item 1 prior to traffic. Typical cross sections taken at 0, 10, 200, and 400 coverages are shown in Figure 27. No cracking was noted in the item up to 200 coverages. After 200 coverages, water was applied, and the pavement kept wet during the second 200 coverages. Traffic was terminated after a total of 400 coverages without failure of the item. At the end of traffic, a few minor hairline cracks were noted in the surface of the pavement, but they did not extend through the asphaltic concrete. Figure 30 shows the overall view of item 1 at termination of traffic. Approximately 0.7 inches of deformation was measured at the center of the traffic lane at termination of traffic (Figure 31).

ITEM 2

Figure 32 shows item 2 prior to traffic. Typical cross sections taken at 0, 10, 200, and 400 coverages are shown in Figure 27. At 40 coverages small hairline cracks were noted in the surface of the asphaltic concrete. At 200 coverages these cracks were more pronounced but did not extend through the asphaltic concrete. Figure 33 shows the cracks at 200 coverages and deformation of approximately 0.75 inches at the centerline of the traffic lane. After 200 coverages water was applied and the pavement kept wet during traffic for the next 200 coverages. During the last 200 coverages, cracks progressed through the asphaltic concrete and in isolated areas through the top membrane of the MESL; therefore, the item was considered failed at 400 coverages. Figure 34 shows an overall view at 400 coverages, and Figure 35 shows deformation of approximately 1 inch that had occurred at the centerline of the traffic lane.

ITEM 3

Figure 36 shows item 3 prior to traffic. Typical cross sections taken at 0, 10, and 25 coverages are shown in Figure 27. Hairline cracks were noted at two coverages and continued to develop with traffic and at 10 coverages were severe, as shown in Figure 37. Deformation at the centerline varied up to about 1.5 inches as shown in Figure 38. Traffic was continued to 14 coverages, then water was applied to the item. Lean clay was observed pumping through cracks in isolated areas; therefore, cracks had penetrated into the

MESL. The item was considered failed at 14 coverages, but traffic was continued to 25 coverages. Figure 39 shows the condition of item 3 at termination of traffic.

ITEM 4

Figure 40 shows item 4 prior to traffic. Typical cross sections taken at 0, 10, and 14 coverages are shown in Figure 27. Slight wrinkling of the surface membrane and consolidation of approximately 1.5 inches, as shown in Figure 41, were noted on one-third of the item nearest to item 3 at two coverages. At six coverages wrinkling progressed to the point that it appeared to be no longer waterproof. Traffic was continued, and at 10 coverages deformation of about 3.5 inches was measured as shown in Figure 42. Wrinkling of the surfacing material was more pronounced, and the item was considered failed. Figure 43 shows the overall condition of the surface at 10 coverages. To verify that the surface was no longer waterproof, water was applied to part of the surface, and four more coverages of traffic were applied. During these coverages, it was evident from rutting that the lean clay had become wet and lost strength so traffic was terminated at 14 coverages.

ITEM 4A

Figure 44 shows item 4A prior to traffic. Typical cross sections are shown in Figure 27. The half of the item located adjacent to the sod section, item 5, was affected by water migrating into the MESL from item 5. Wrinkling of the surface of the artificial turf occurred under traffic, and the material pulled loose from the surface of the MESL causing it not to conform to permanent deformation in ruts. No tears or other damage were noted in the material under traffic. After 10 coverages of traffic, permanent deformation of 2.5 inches, as shown in Figure 45, was measured. Traffic was terminated after 10 coverages, and the item considered failed due to the material tearing loose from the MESL surface and rut depth approaching depth required for failure. Figure 46 shows the surface after 10 coverages.

ITEM 5

Figure 47 shows item 5 prior to traffic. The item failed on the first pass of the load cart during the rolling-wheel drawbar pull test. A rut depth of about 4 inches, as shown in Figure 48, developed as the load cart was towed onto the item. Moisture had penetrated through the surface of the MESL into the lean clay, causing a loss in strength of the MESL.

DEFLECTION MEASUREMENTS

Static deflection measurements were made at the center of items 1 through 4. These measurements were obtained with level instruments by reading rods (engineer scales) at prearranged positions on lines transverse to the direction of traffic. Rod readings were first taken with the load off the surface. The test cart was moved until the load wheel was at the prearranged position, and a second series of readings was taken on each side of the wheel with the load on. The load cart was moved away from the position, and after 5 minutes a third series of readings was taken to determine permanent deformation.

Deflection measurements were taken in items 1 and 2 at 0, 10, and 112 coverages; in item 3 at 0 and 10 coverages, and in item 4 at 0 coverages. Plots of deflection measurements are shown in Figure 49. These plots show that the deflection in item 1 decreased with the application of traffic. In item 2 the deflection decreased from 0 to 10 coverages, but at 112 coverages the deflection was greater than at 0 coverages. In item 3 the deflection increased from 0 to 10 coverages. Deflections were taken only at 0 coverages in item 4 because at 10 coverages the load wheel continued to sink when it was stopped on the item. Permanent deformation measured at the center of the load wheel, after the load wheel had been removed for 5 minutes, at 0 coverages was 0.4, 0.4, 0.7, and 0.9 inches for items 1, 2, 3, and 4, respectively. At 10 coverages permanent deformation was 0.2, 0.4, and 0.6 inches for items 1, 2, and 3, respectively. At 112 coverages permanent deformation was 0.1 and 0.2 inches for items 1 and 2, respectively.

AFTER-TRAFFIC TESTING

After traffic was terminated, trenches were cut across the traffic lane into untrafficked areas to determine the extent of distortion of the surfacing material, MESL, and subgrade. In-place CBR tests were conducted and water content and density determinations were made in the MESL and subgrade at the depths shown in Table 2. Level readings were taken on the surface of each test item, surface of the MESL, and subgrade in each test trench and are shown in Figure 27, along with level readings taken during construction and at various coverages of traffic.

ITEM 1

The profile of the test trench (Figure 27) shows that deformation at the surface of the asphaltic concrete and at the surface of the MESL was approximately the same. The profile also shows that deformation at the surface of the MESL was about 0.3 inches more than at the surface of the subgrade. In-place tests taken after traffic shows that the density in the MESL increased 2.1 lb/cu ft, the water content was approximately the same, and the CBR increased from an average of 21 to an average of 34. The increase in CBR is due to densification from traffic.

In-place tests on the subgrade show that the density in the top 6 inches of the subgrade increased 6.7 lb/cu ft and remained about the same below 6 inches. The water content in the top 6 inches decreased 4.3 percent, but below 6 inches there was no significant change. The CBR values increased at the surface from 6 to 13 and at 6 inches from 7 to 9 but were unchanged at 12 inches. This increase in CBR is due to the lower water content and an increase in density in the material. Figure 50 shows the test trench after the lean clay material in the MESL had been removed. As shown, the polyethylene membrane used at the bottom of the MESL had worked to the edge of the traffic lane and folded in an accordion fashion. The tears in the membrane occurred when the lean clay was removed. Tension in the membrane in the traffic lane was enough that when the lean clay was removed the membrane separated without any additional pull.

ITEM 2

The profile of the test trench (Figure 27) shows that deformation at the surface of the asphaltic concrete and at the surface of the MESL was approximately the same. The profile also shows that deformation at the surface of the MESL was about 0.3 inches more than at the surface of the subgrade. In-place density tests taken after traffic show that the density in the MESL increased 5.8 lb/cu ft, the water content did not change, and the CBR increased from 21 to 33. The increase in CBR is due to densification from traffic.

In-place tests on the subgrade show that the density in the top 6 inches of the subgrade increased 6.5 lb/cu ft and was unchanged below 6 inches. The water content in the top 6 inches decreased 3.3 percent, but remained about the same below 6 inches. CBR values after traffic were slightly higher due to the loss in moisture content and increased density.

Figure 51 shows the test trench after the lean clay material in the MESL was removed. As shown, the polyethylene membrane used at the bottom of the MESL had worked to the edges, as in item 1, but in this item the membrane had torn; therefore, the MESL was no longer waterproof at the bottom.

ITEM 3

The profile of the test trench (Figure 27) shows that deformation at the surface of the pavement and the surface of the MESL was approximately the same and that the surface of the subgrade had about 0.6 inches less deformation than the surface of the MESL. In-place tests show that the density in the MESL increased 7.5 lb/cu ft, the water content decreased 0.5 percent, and the CBR increased from 24 to 27. Tests were conducted in an area where water applied to the pavement surface had not penetrated through cracks.

In-place tests on the subgrade show that the water content and density were about the same after traffic as during construction, but the CBR had increased from 7 to 9. Figure 52 shows the slab of asphaltic concrete removed from the test trench, cracks that developed the full depth of the pavement, and wet lean clay that adhered to the top membrane when asphaltic concrete was removed. Figure 53 shows that the polyethylene membrane at the bottom of the MESL was intact but began to fold at the edge of the traffic lane.

ITEM 4

The profile of the test trench (Figure 27) shows that deformation at the surface of the MESL was about 1 inch more than at the surface of the subgrade and that approximately 1 inch of upheaval occurred at the edge of the traffic lane. In-place tests taken on the subgrade after traffic shows that the average density increased 6.8 lb/cu ft, the CBR increased from an average of 22 to 30, and the water content was the same before traffic and after traffic. The polyethylene membrane at the bottom of the MESL was not torn or wrinkled.

ITEM 4A

Tests were not conducted under the synthetic turf because water had migrated into the area from item 5 and performance varied. The 6 feet of item 4A adjacent to item 4 performed as item 4, and the approximate 6 feet of the item adjacent to item 5 failed immediately after traffic began.

ITEM 5

The profile of the test trench (Figure 27) shows deformation and upheaval that occurred with one pass of the load cart. As shown, most of the deformation occurred in the lean clay used in the MESL. In-place tests show no significant change in density in either the MESL or subgrade, but the water content in the MESL increased 6 percent and the CBR decreased from 23 to an average of 9.5.

Figure 54 shows the test trench and the rut that occurred at one pass. The polyethylene membrane on the bottom of the MESL was not torn. Failure in this item was caused by water that was applied to the sod soaking through the top membrane of the MESL and saturating the lean clay causing a loss in strength of the encapsulated soil.

AFTER-TRAFFIC TESTS OF ASPHALTIC CONCRETE

The results of laboratory tests on cores taken after termination of traffic are shown in Table 1. Cores were taken in items 1, 2, and 3 both inside and outside the traffic lane for comparative purposes. These tests show that the density in items 1 and 2 increased from about 97 percent of 75-blow laboratory density to about 98.5 percent of laboratory density. Item 3 was severely cracked in the traffic lane and the density decreased from 97.3 percent of laboratory density to 94.4 percent. This decrease is probably due to small cracks in the cores because the asphaltic concrete was severely cracked at the termination of traffic.

SECTION IV
CONCLUSIONS

Based on data obtained from this study, the following conclusions are believed warranted.

1. A thin fine-grained soil base course can be successfully constructed and encapsulated in a waterproof protective membrane over a subgrade with a CBR of 7 if the fine-grained material is placed in a loose layer of 12 inches and then compacted.

2. A membrane-encapsulated fine-grained soil base course 7 inches thick with 2 inches of asphaltic concrete over a 7 CBR subgrade will withstand 14 coverages (approximately 140 passes) of F-4C traffic in a 10-foot-wide traffic lane.

3. A membrane-encapsulated fine-grained soil base course 9 inches thick with only the waterproof surfacing will withstand 10 coverages (approximately 96 passes) of F-4C traffic; however, wrinkling and movement of the membrane on the surface of the encapsulated soil may render the surfacing susceptible to water before 10 coverages.

4. Synthetic turf will withstand the rolling wheel load for 10 coverages but will not stay adhered to the MESL surface when tacked with emulsified asphalt as used in this study.

5. A MESL is susceptible to infiltration of water when overlaid with a layer of wet material such as the sod used in this study.

6. Under accelerated traffic as applied in this study, membranes used for waterproofing the bottom of a MESL work toward the outside edge of the traffic lane. If traffic is applied at random, as would occur in actual operations, this probably would not occur.

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1. Burns, C. D. and Brabston, W. N., "Membrane-Enveloped Technique for Waterproofing Soil Base Courses for Airstrips; Bare Base Support," Miscellaneous Paper S-68-13, Jul 1968, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

2. Webster, S. L. and Andress, R. A., "Investigation of Fabrics and Bituminous Surfaces for Use in MESL Construction," Miscellaneous Paper S-76-14, Aug 1976, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

3. U. S. Air Force Weapons Laboratory, Air Force Systems Command, "Multiple-Wheel Heavy-Gear Load Pavement Tests," AFWL-TR-70-113, Vols I-IV (in five volumes), Nov 1971, Kirtland AFB, New Mexico, prepared by U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss., and distributed as Technical Report S-71-17.

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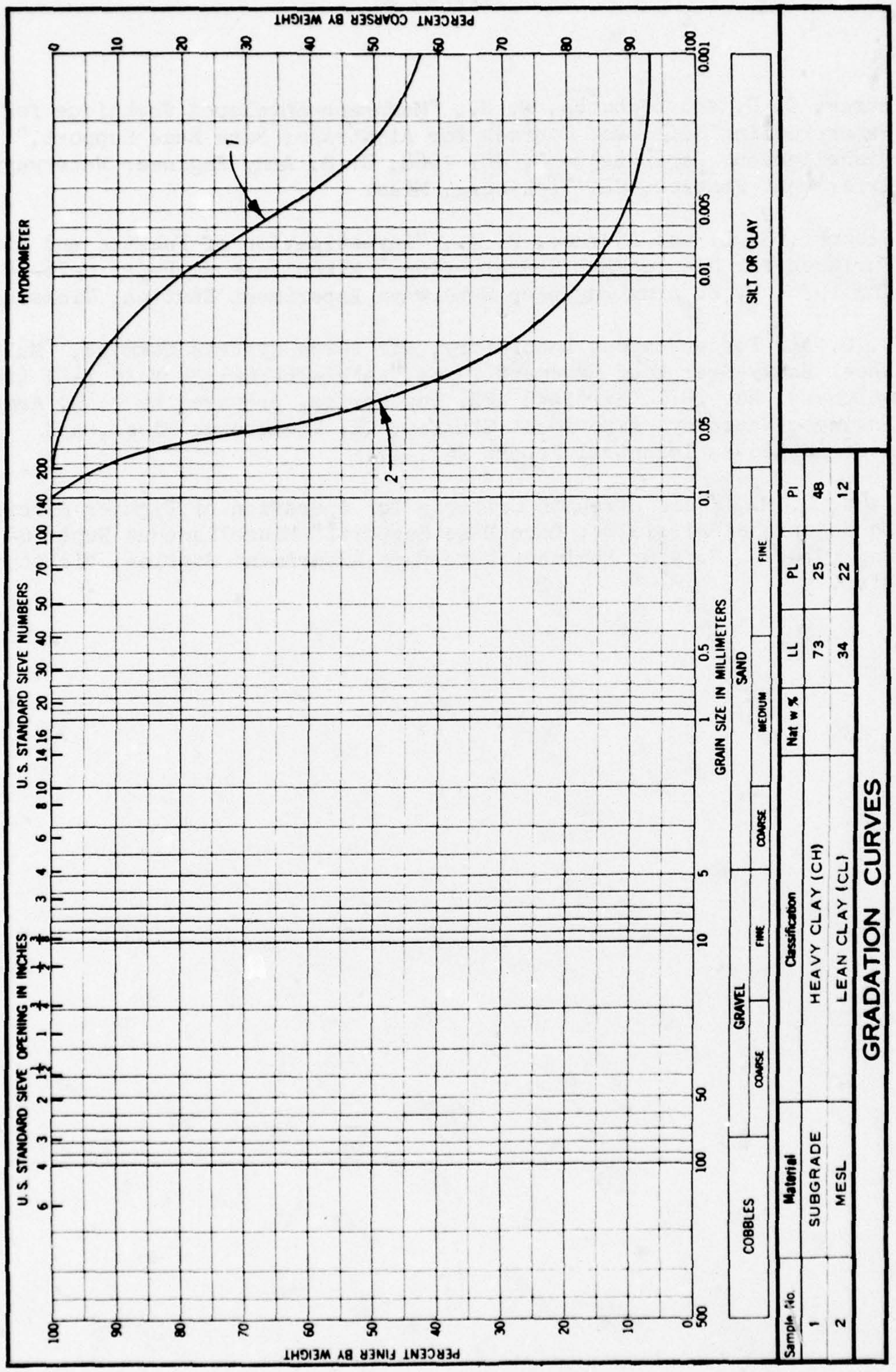


Sample No.	Material	Classification	Nat w %	LL	PL	PI
1	SUBGRADE	HEAVY CLAY (CH)		73	25	48
2	MESL	LEAN CLAY (CL)		34	22	12

Figure 1. Classification Data

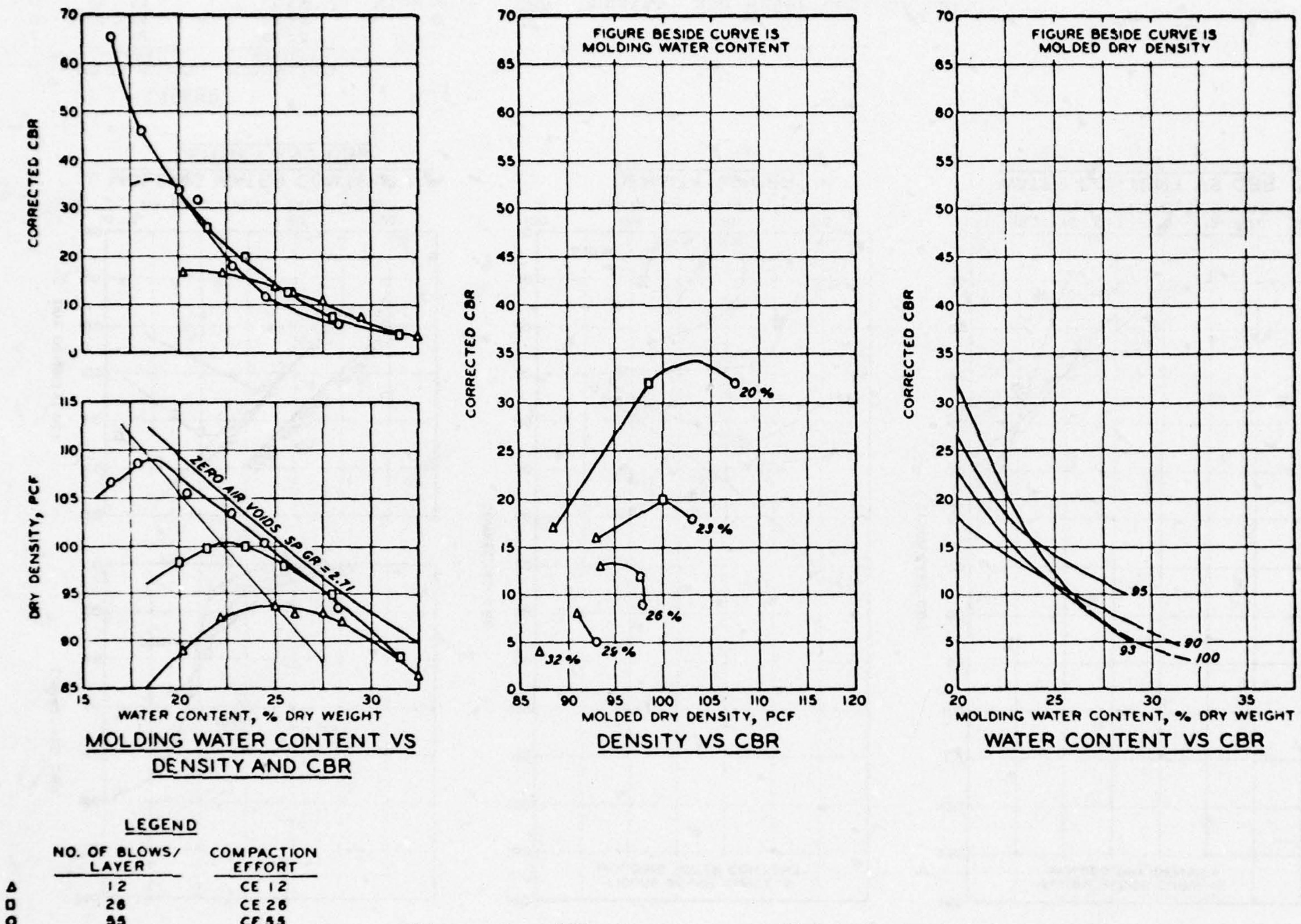
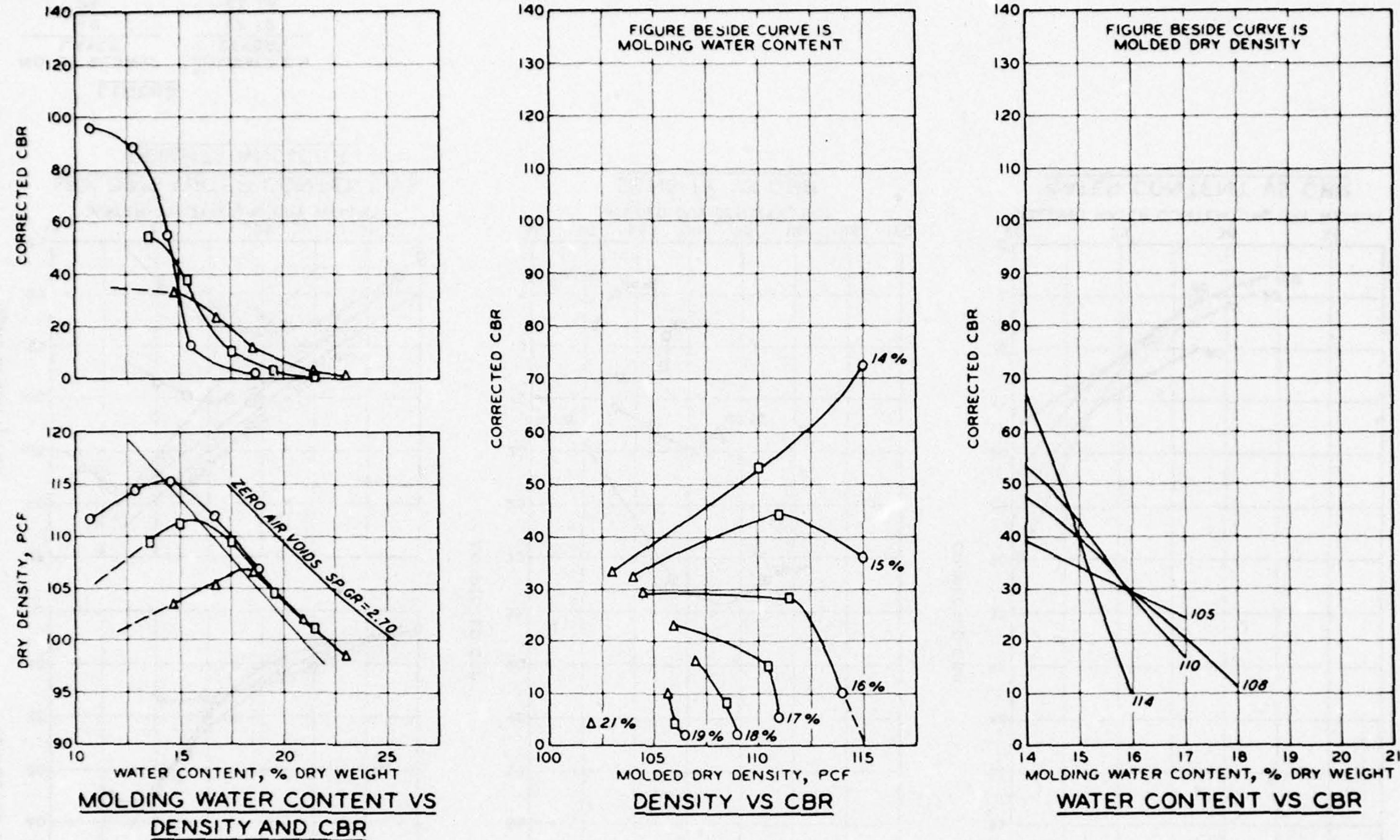


Figure 2. CBR, Density, and Water Content Data
(Heavy Clay Subgrade Tested as Molded)



LEGEND

	NO. OF BLOWS/ LAYER	COMPACTION EFFORT
Δ	12	CE 12
□	26	CE 26
○	55	CE 55

Figure 3. CBR, Density, and Water Content Data
(Lean Clay MESL Material Tested as Molded)

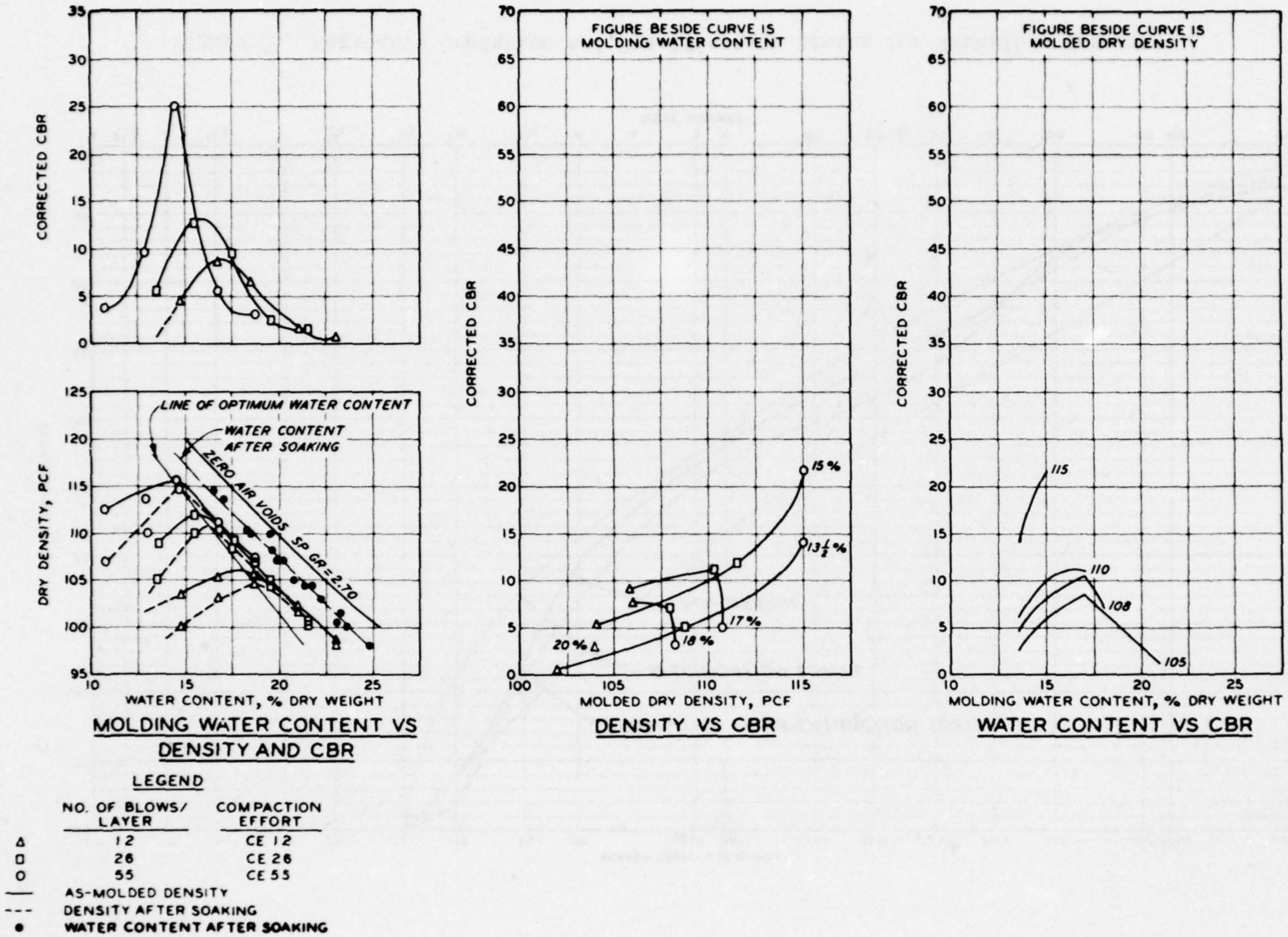


Figure 4. CBR, Density, and Water Content Data
(Lean Clay MESL Material Tested After Soaking)

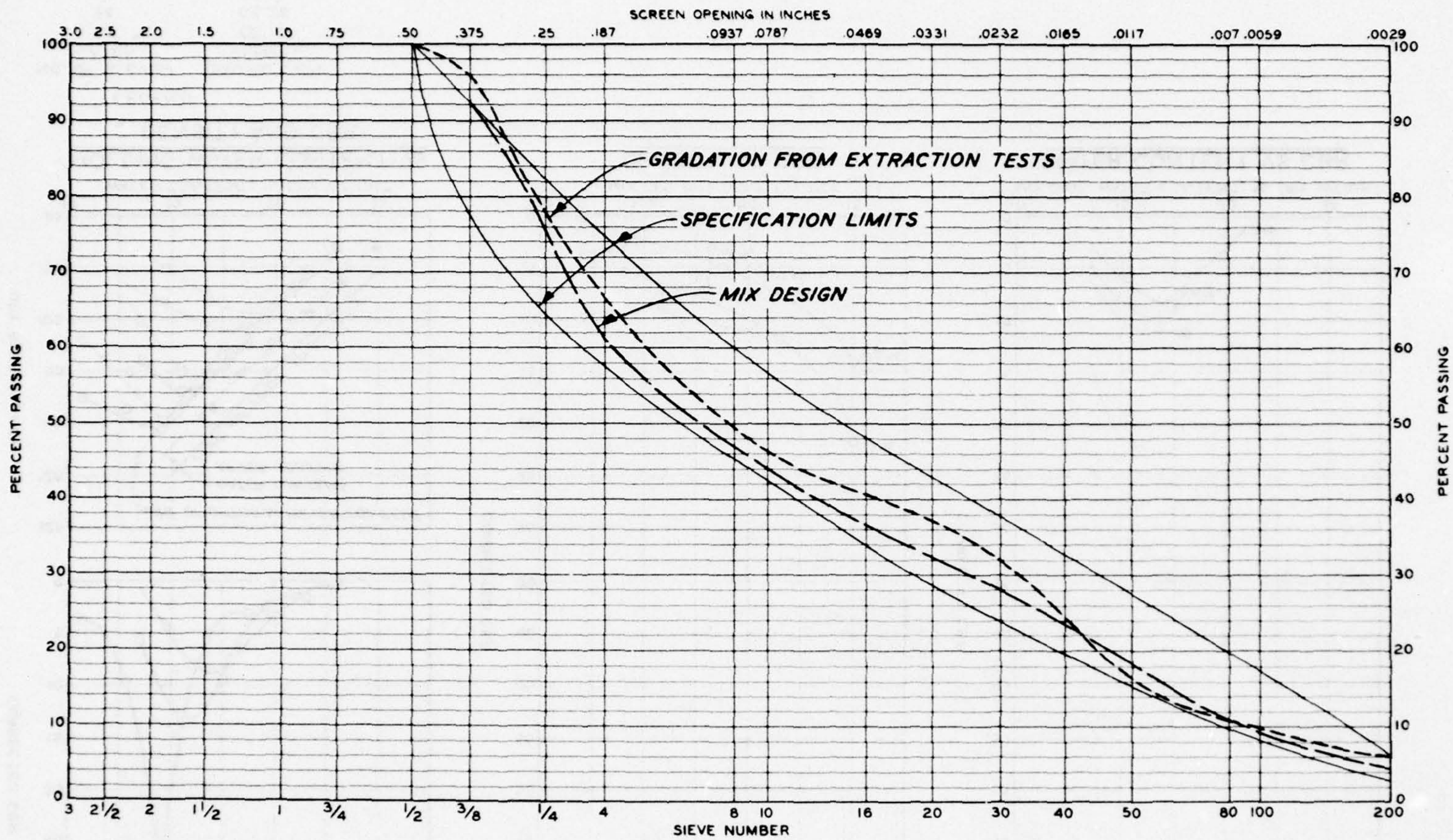


Figure 5. Aggregate Gradation and Specification Limits for Asphaltic Concrete

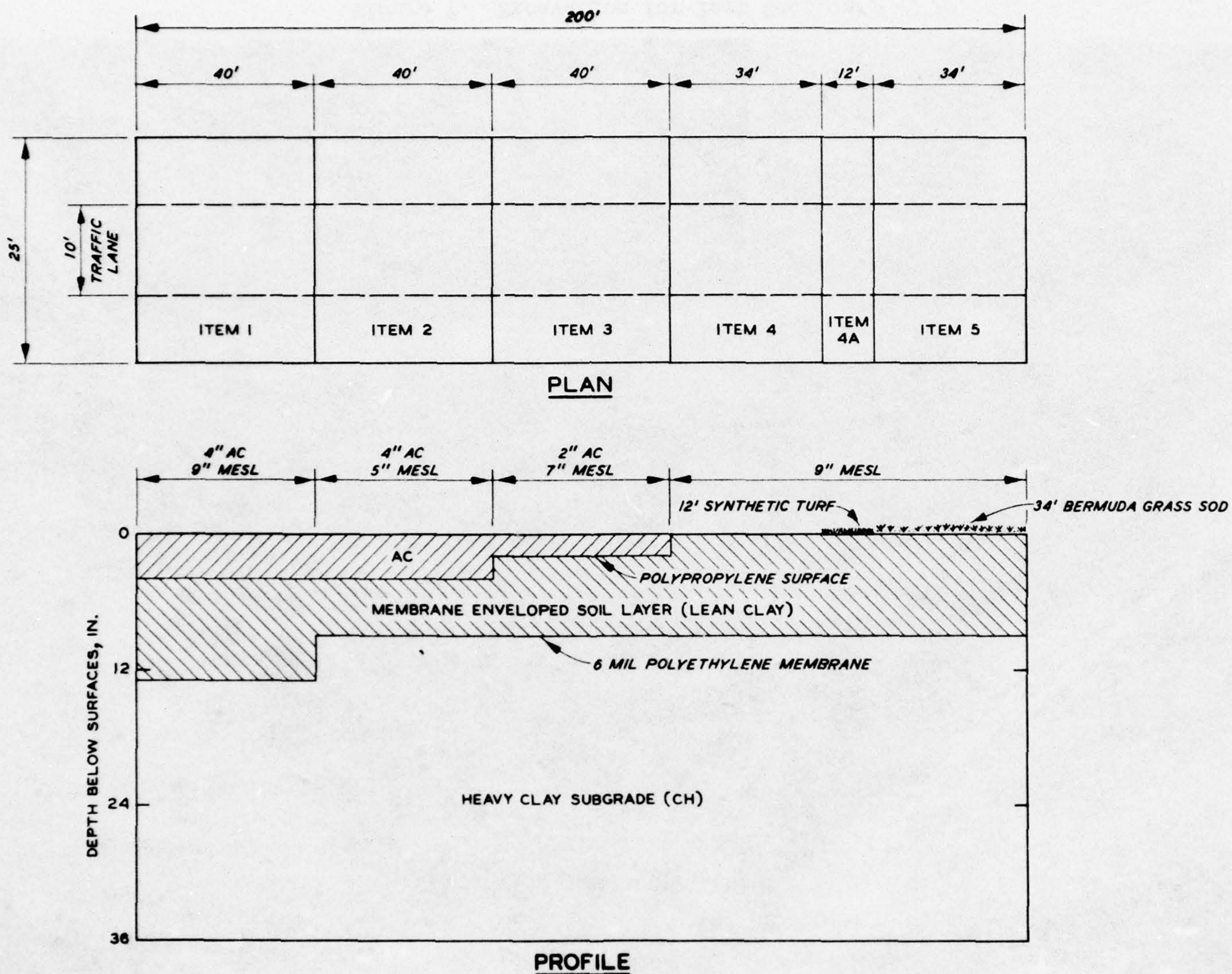


Figure 6. Plan and Profile of Test Section

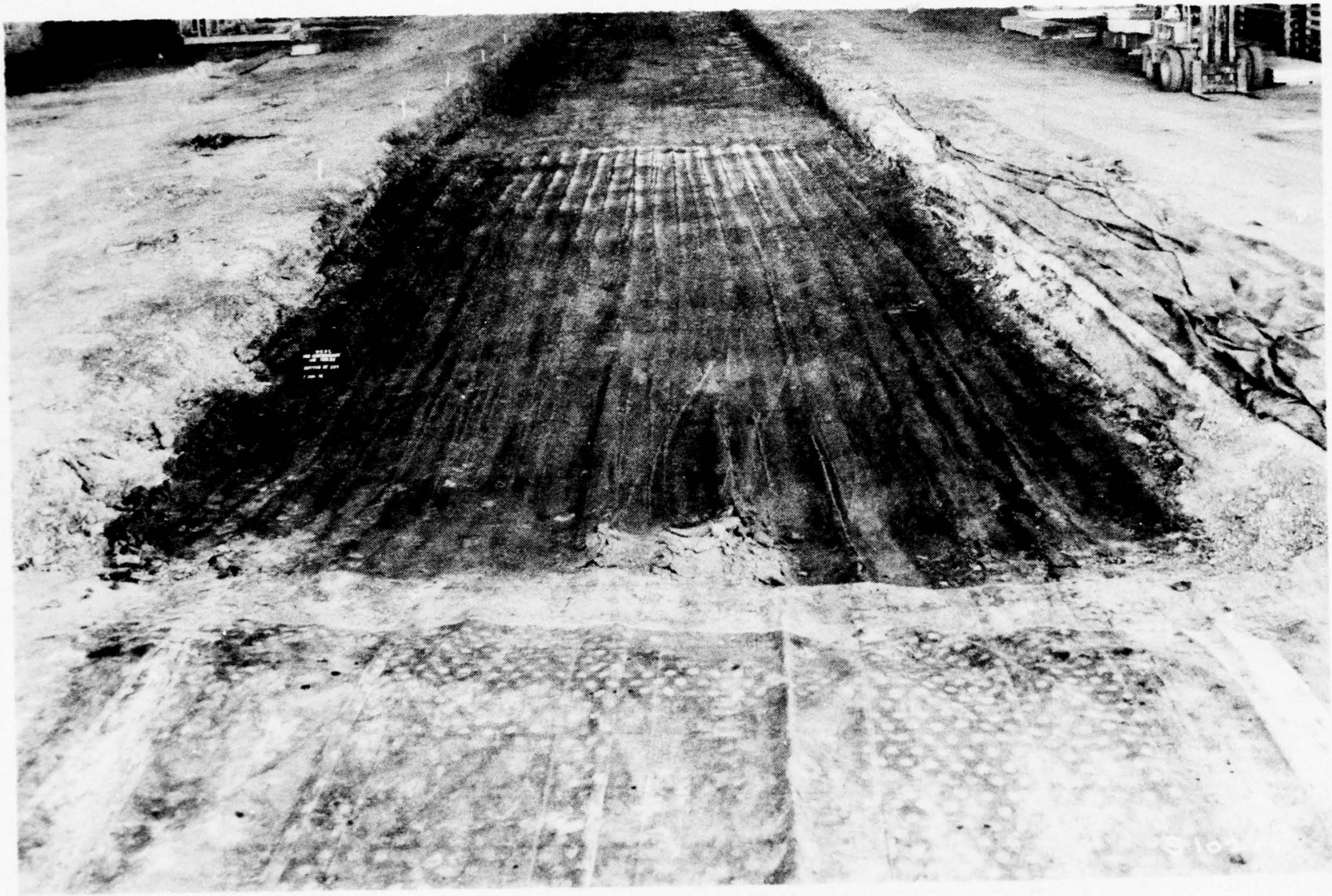


Figure 7. Excavation for Test Section

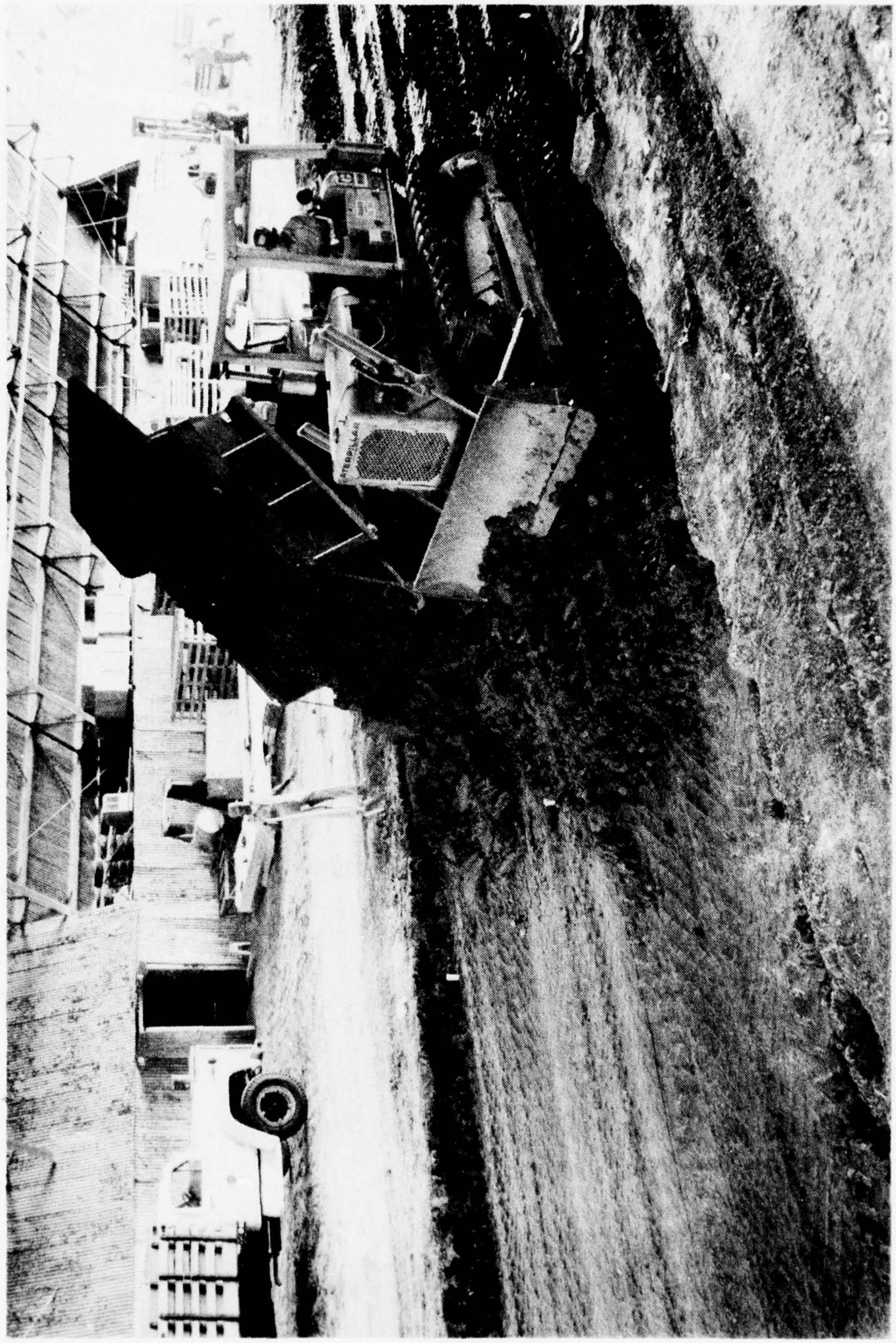


Figure 8. Placing Heavy Clay Subgrade

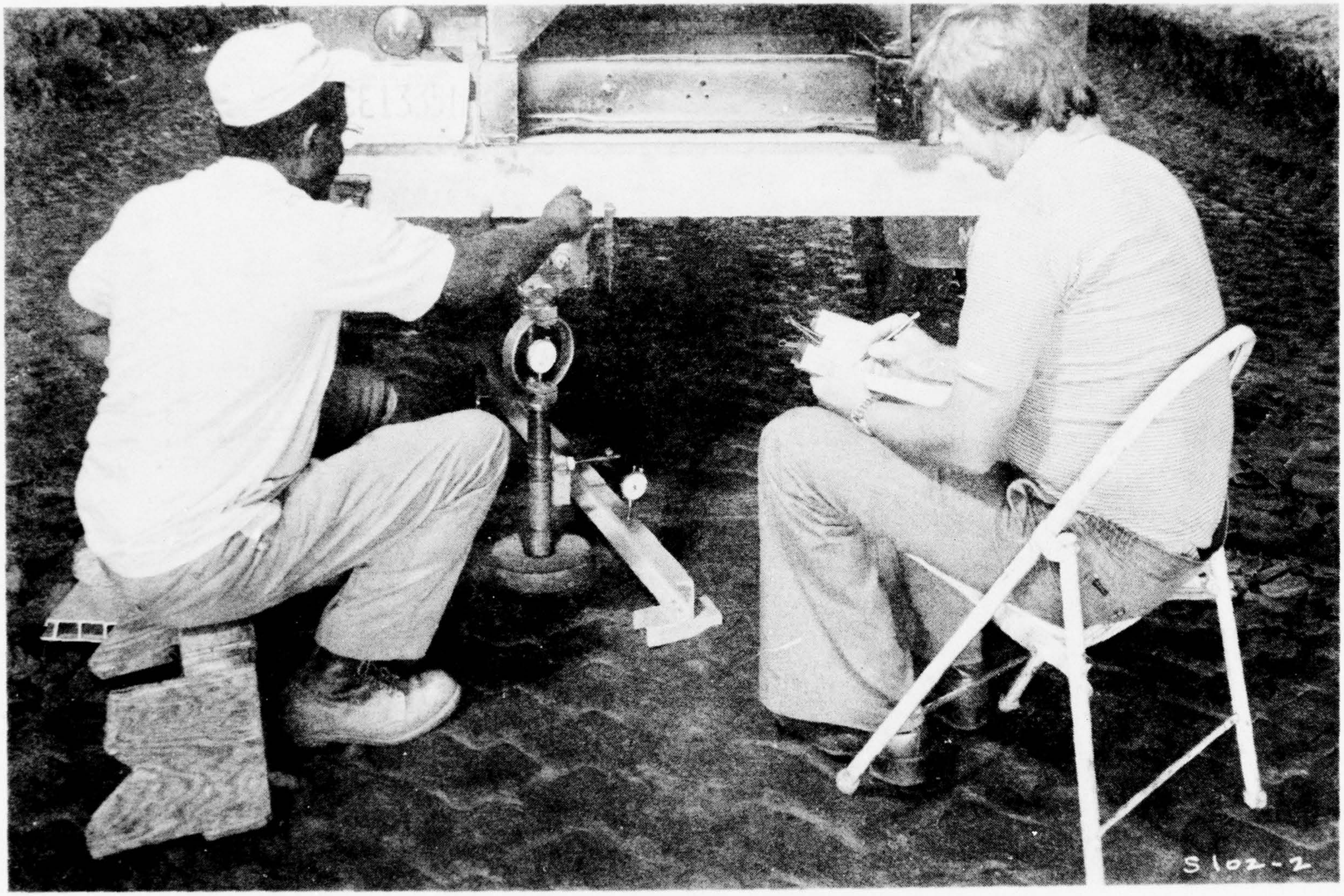


Figure 9. In-Place CBR Testing on Subgrade

Figure 10. Finished Surface of Subgrade

Figure 11. Overlap of Polyethylene at Edge of Lean Clay MESL

Figure 12. Placing Lean Clay on Polyethylene Covered Subgrade

Figure 13. Spreading Lean Clay for MESL

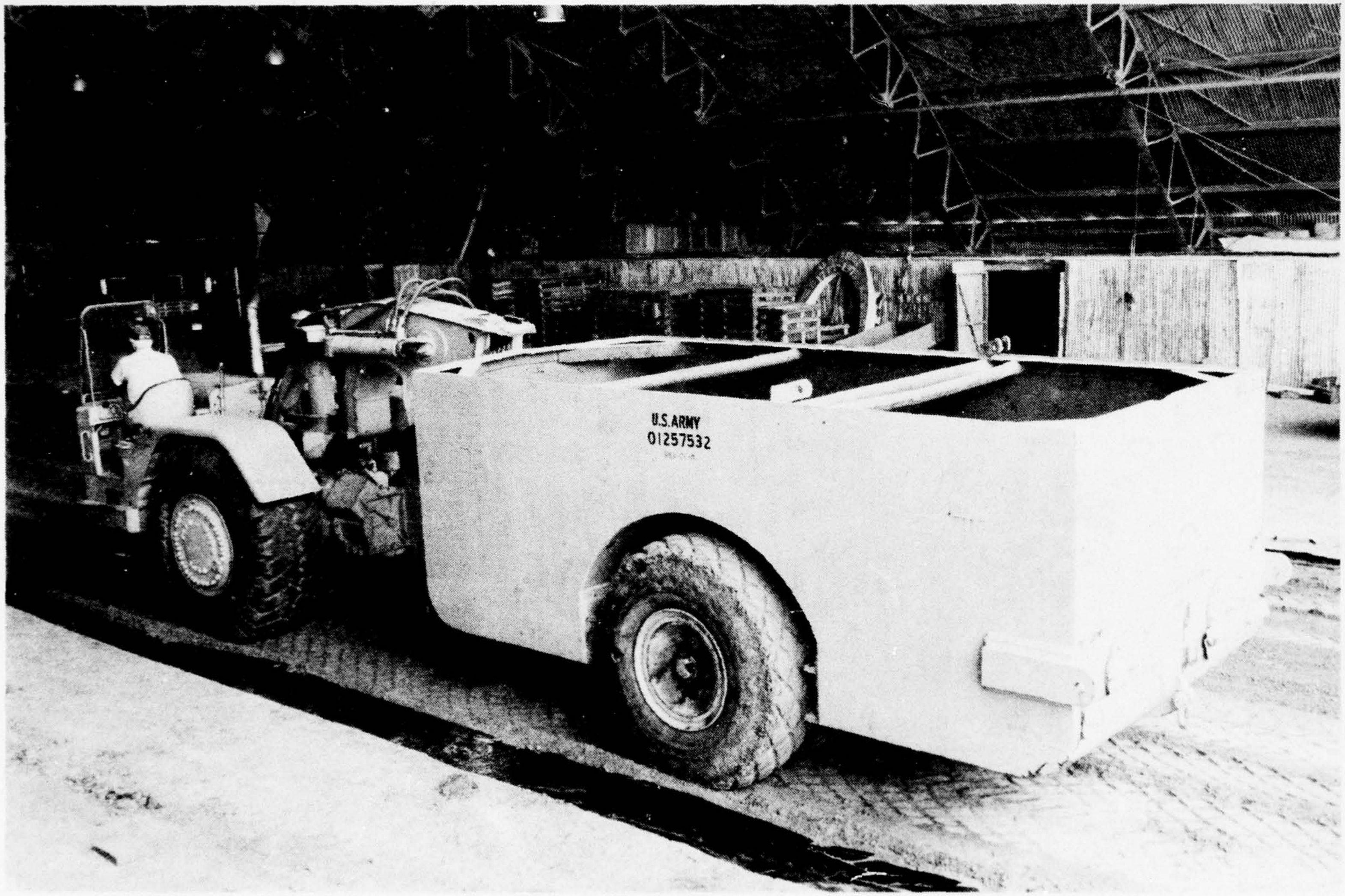


Figure 14. Compacting Lean Clay MESL with 50-Ton Pneumatic-Tired Roller

Figure 15. Cracks in Surface of Finished Lean Clay

Figure 16. Fine Grading Surface of Lean Clay

Figure 17. Finished Surface of Lean Clay with Polyethylene Folded Over Edges

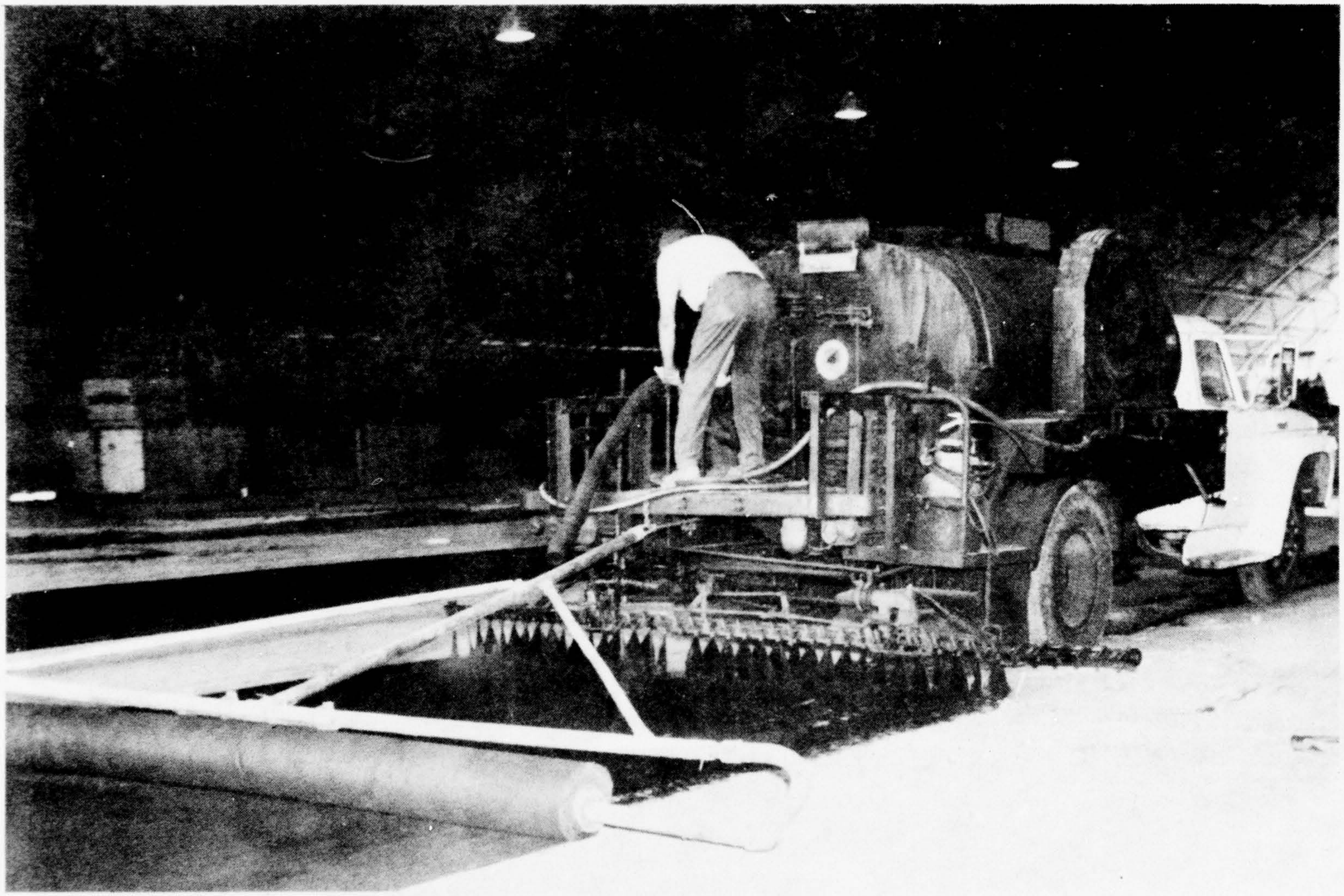


Figure 18. Applying Emulsified Asphalt to Surface of Lean Clay and Placing Polypropylene Membrane

Figure 19. Rolling Surface of MESL

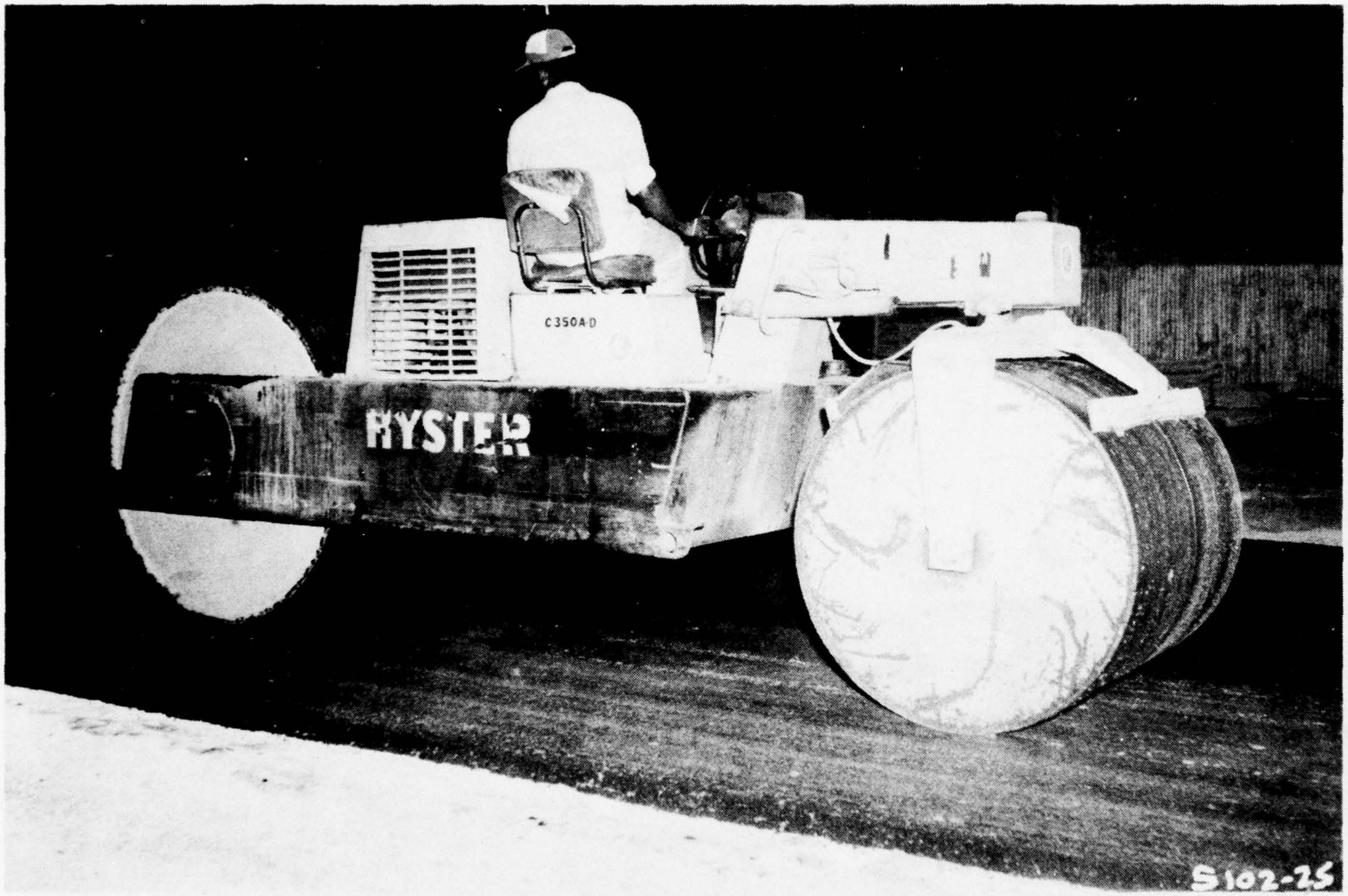


Figure 20. Break-Down Rolling of Asphaltic Concrete

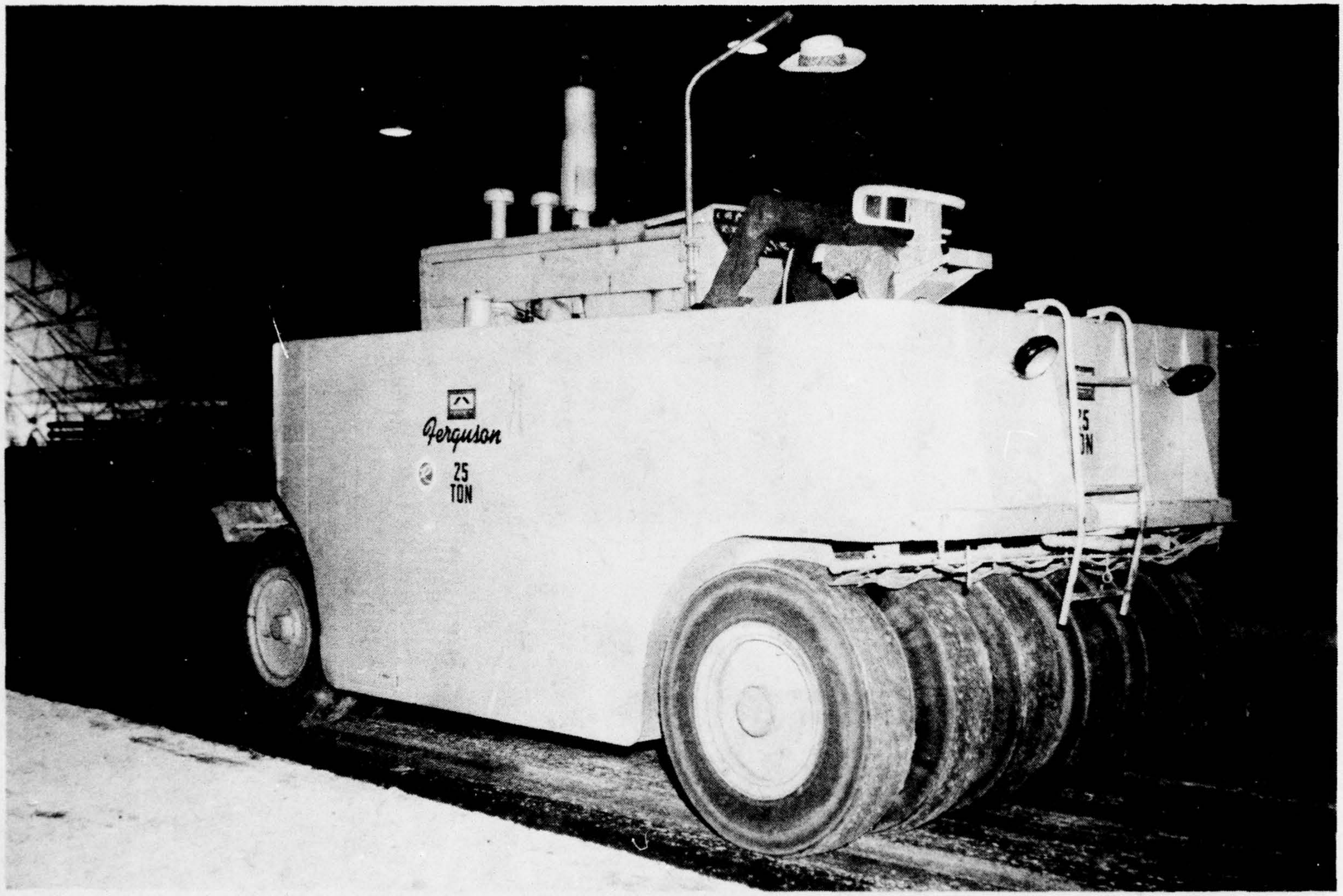


Figure 21. Compacting Asphaltic Concrete with Pneumatic-Tired Roller

Figure 22. Placing Sod on Item 5

Figure 23. Rolling Sod

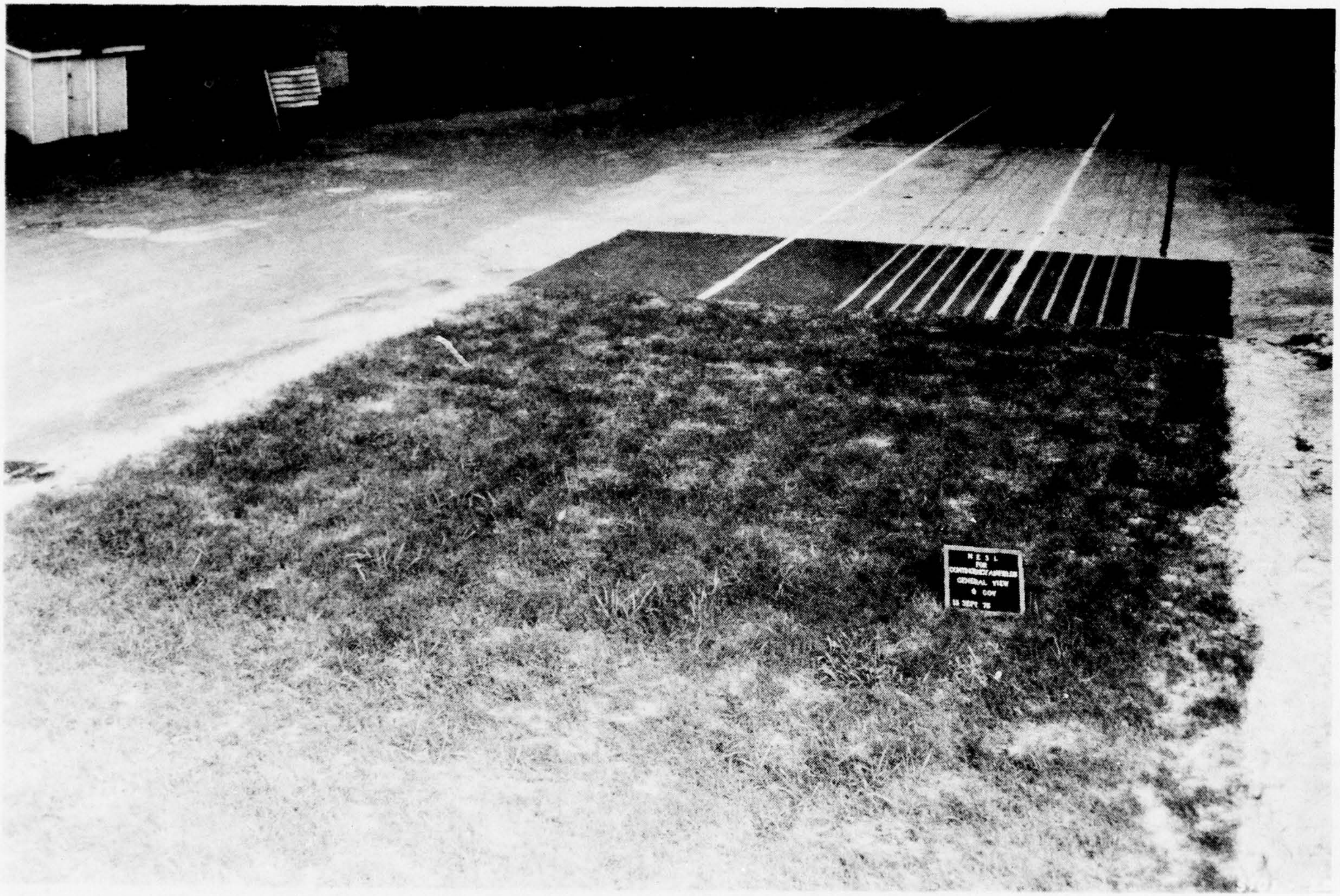


Figure 24. Overall View of Test Section Prior to Traffic

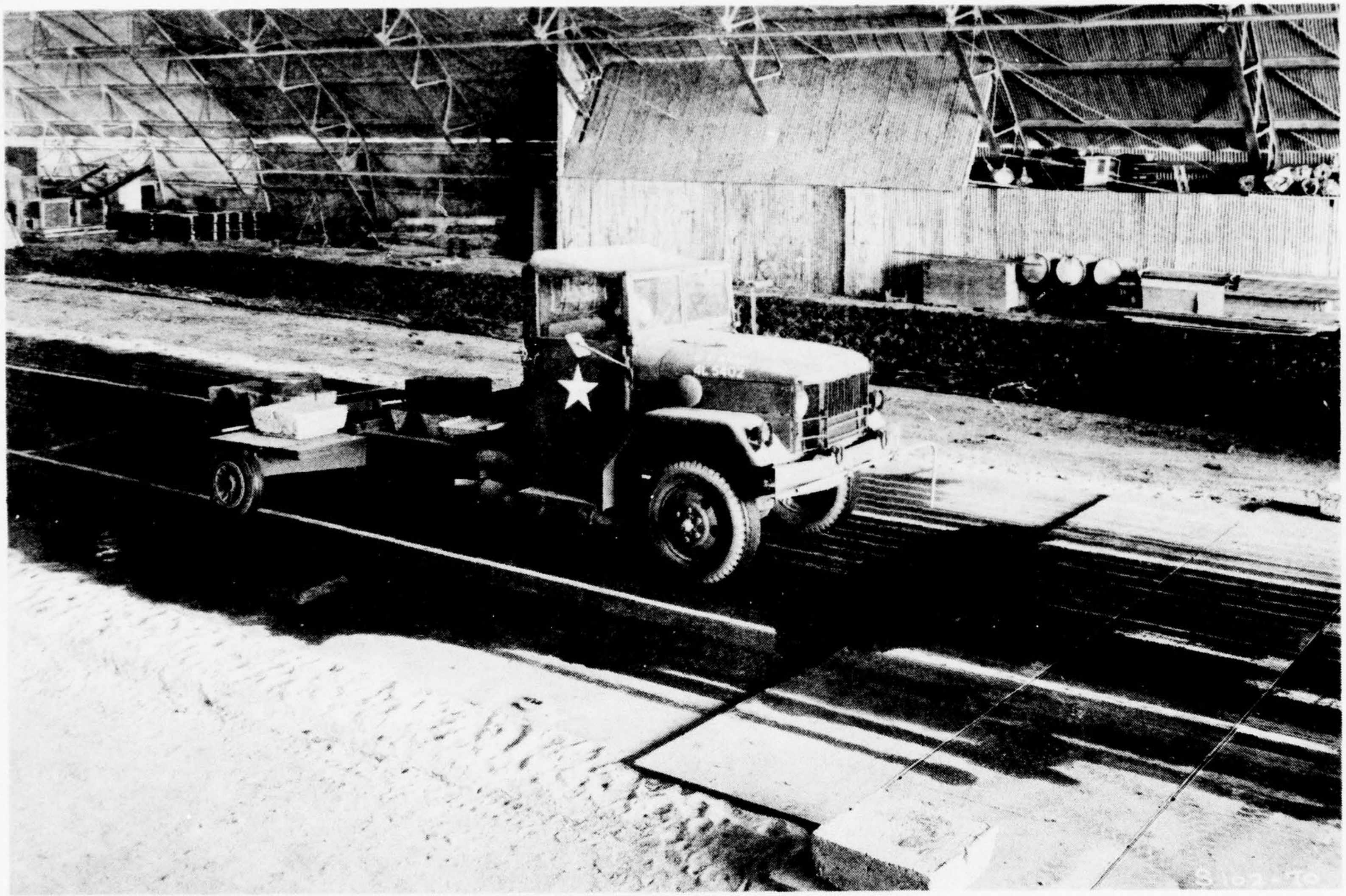


Figure 25. Load Cart Used in Traffic Test

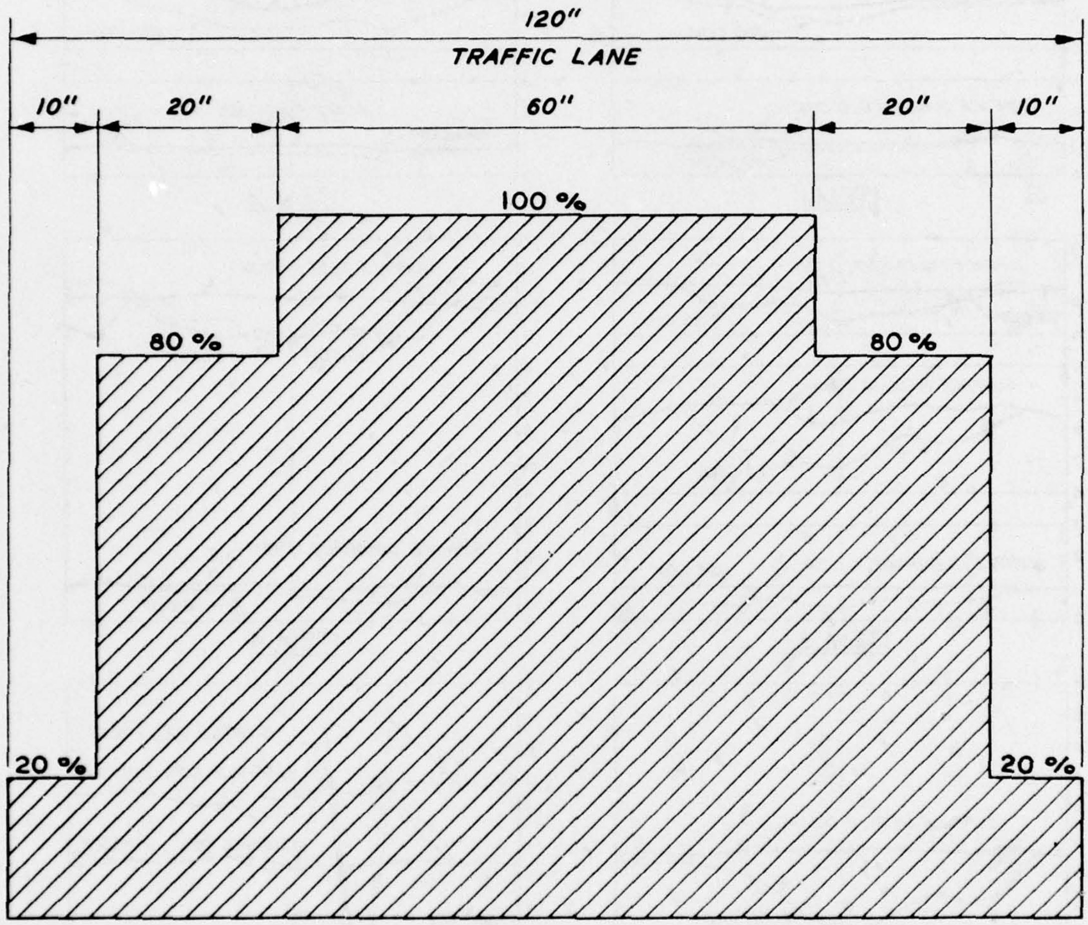


Figure 26. Traffic Distribution Pattern

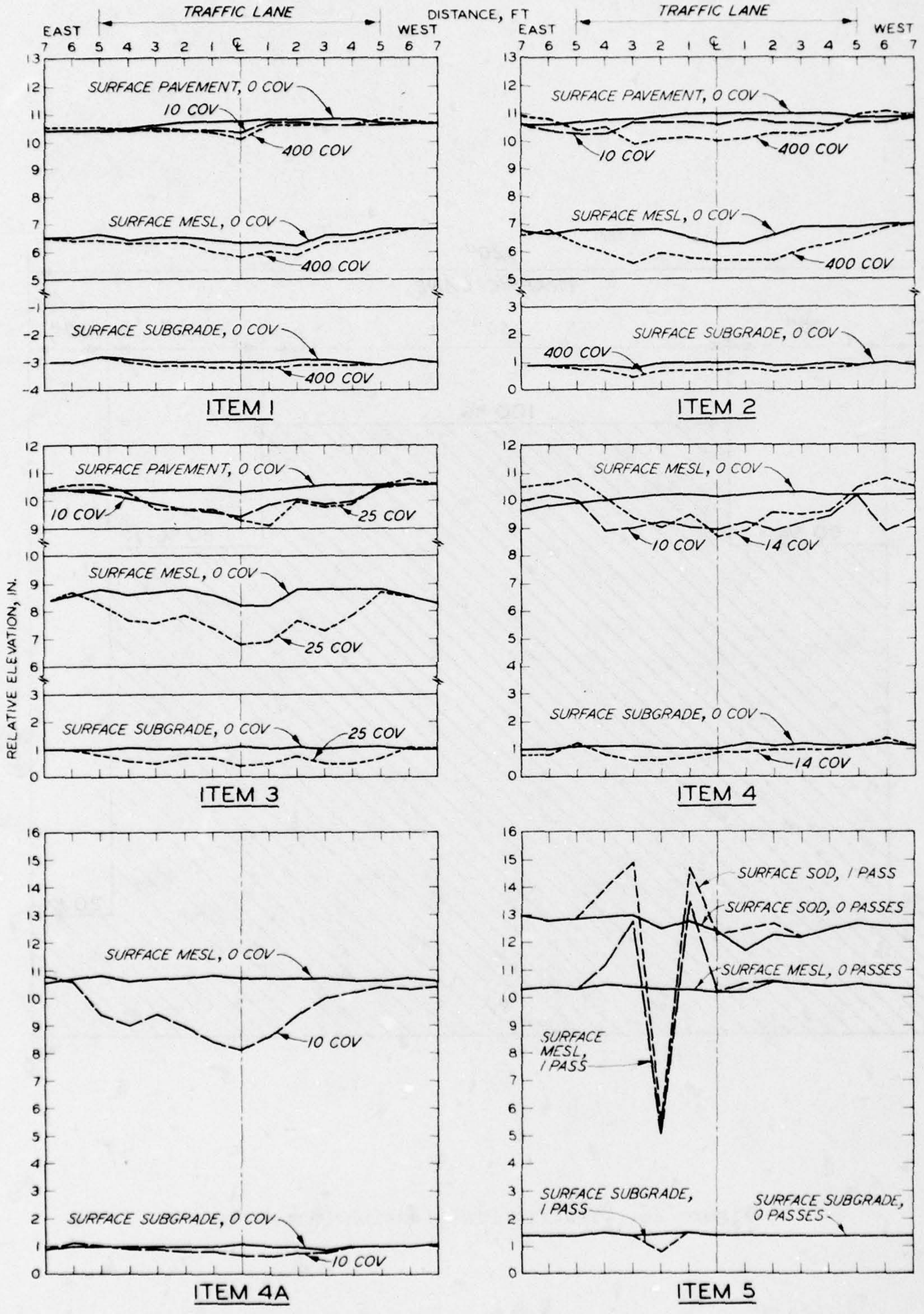


Figure 27. Typical Cross-Sections

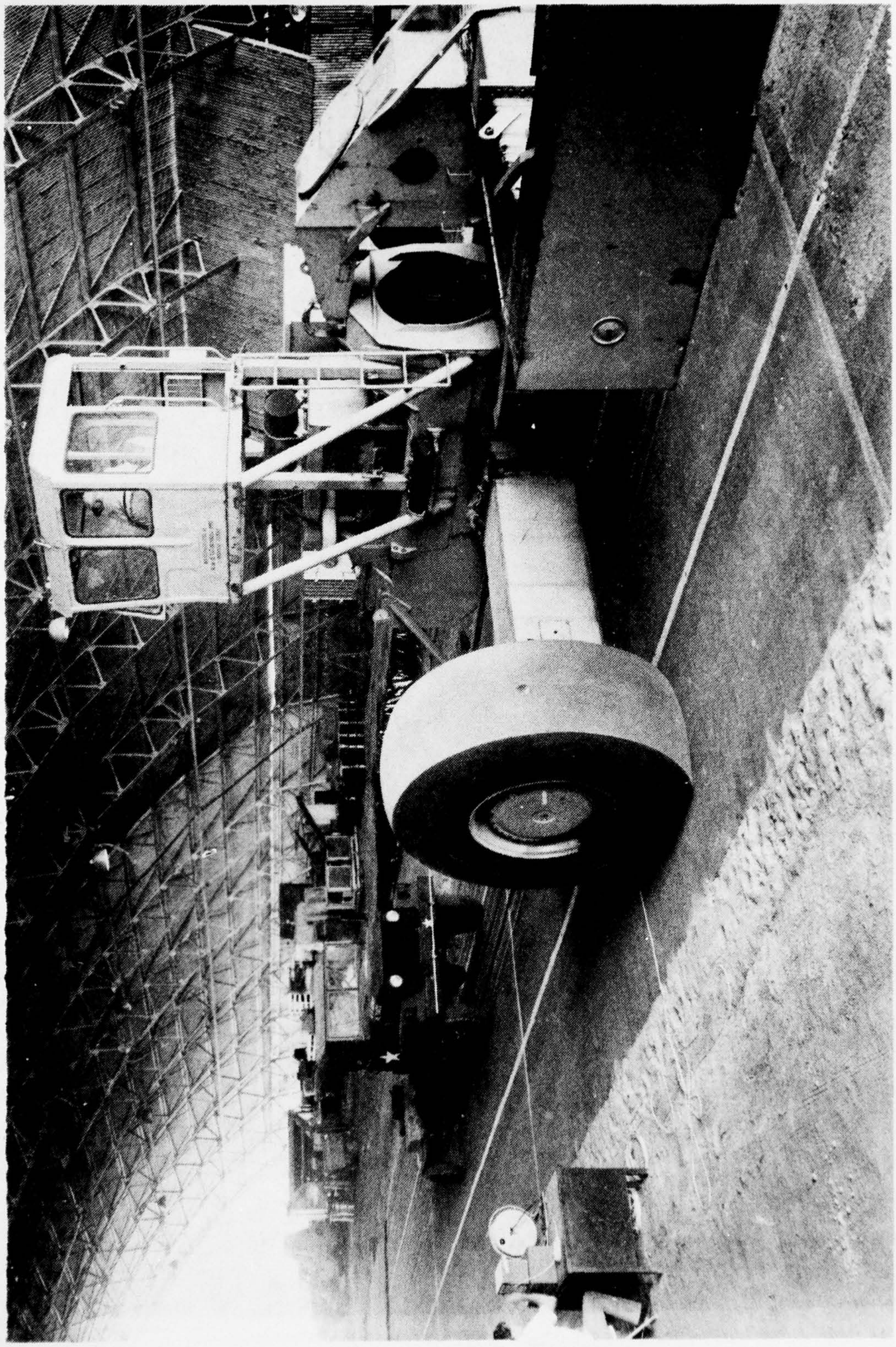


Figure 28. Rolling Wheel Drawbar Pull Determination

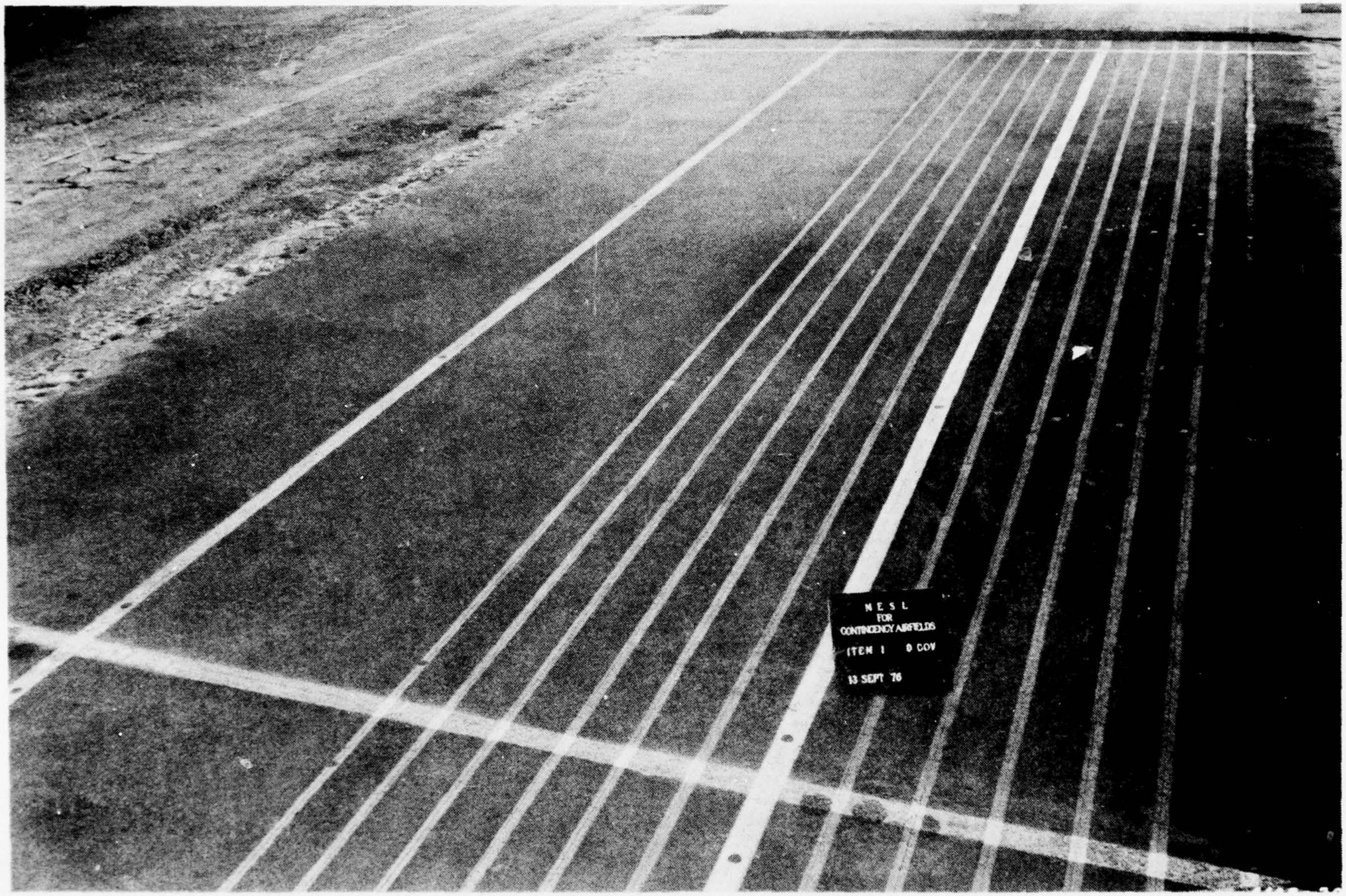


Figure 29. Item 1 Prior to Traffic

Figure 30. Item 1 After 400 Coverages

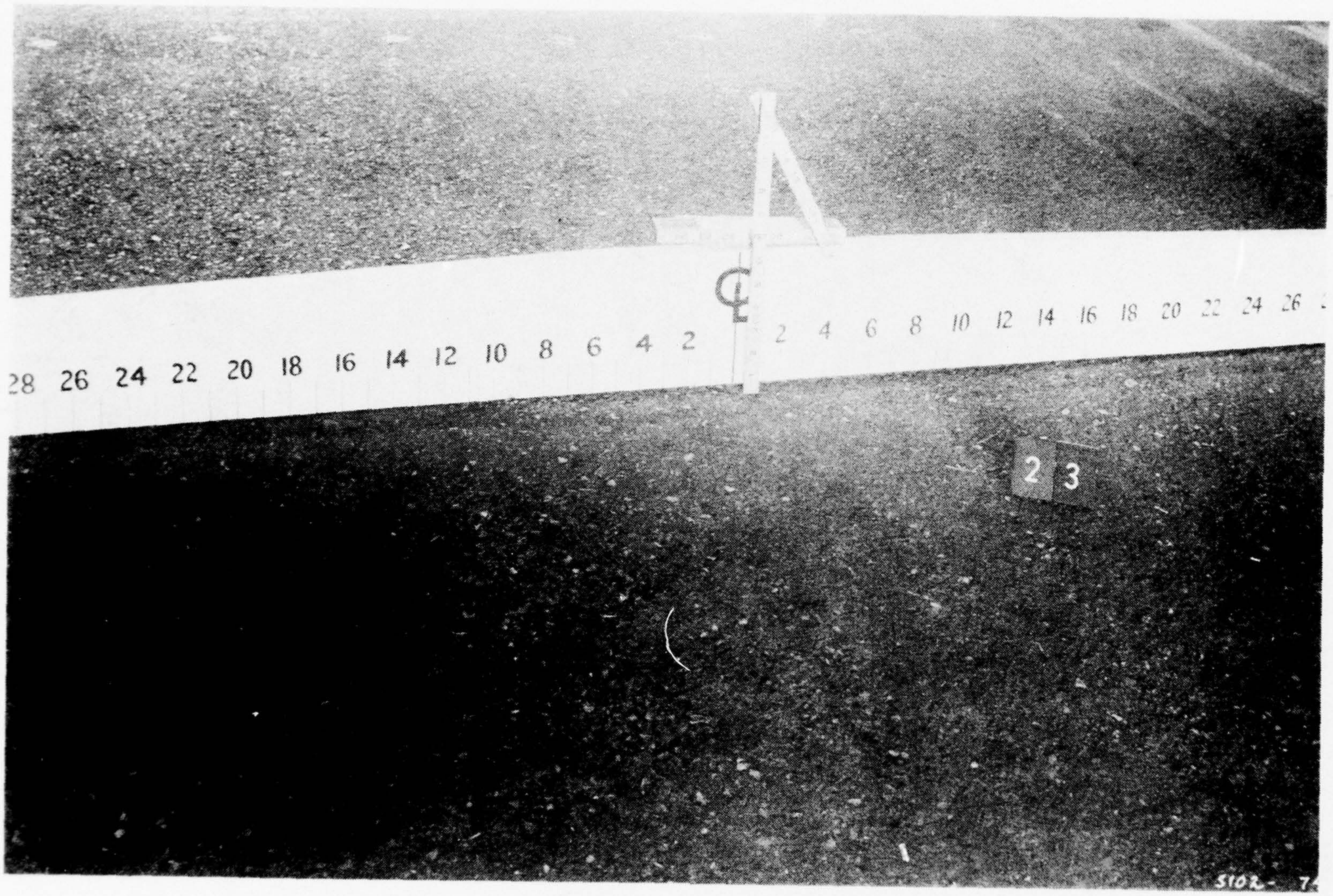


Figure 31. Deformation in Traffic Lane, Item 1, 400 Coverages

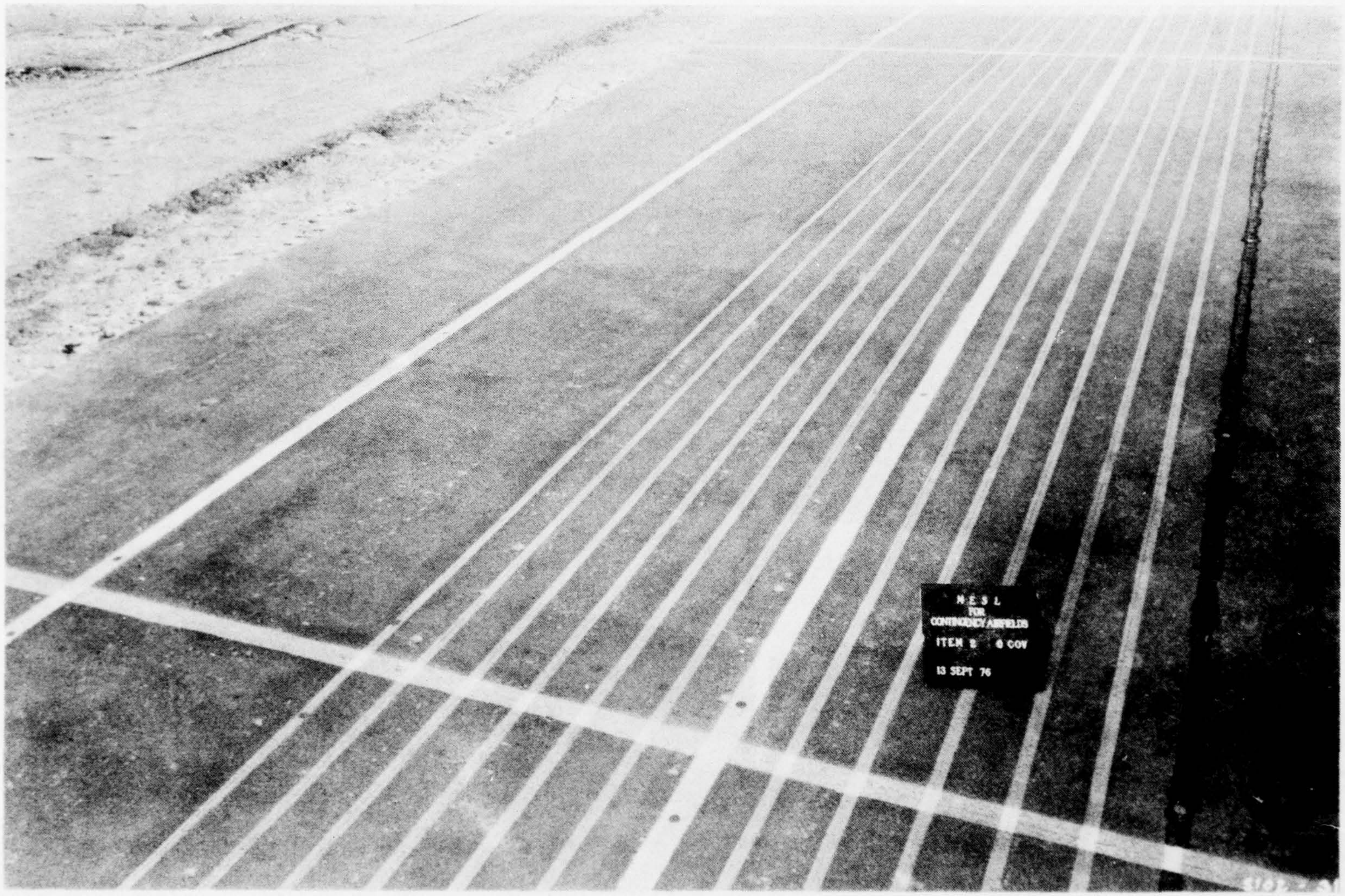


Figure 32. Item 2 Prior to Traffic

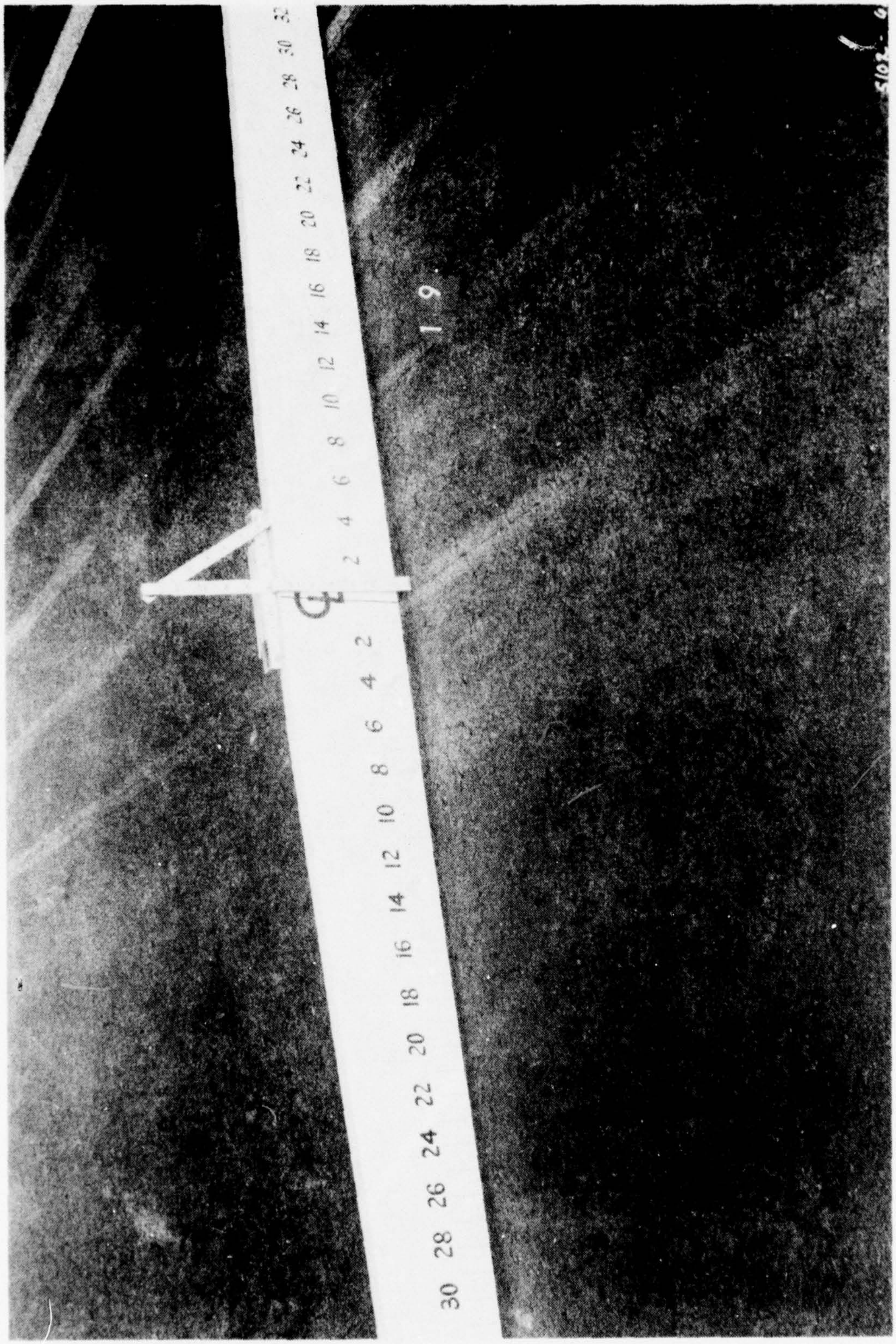


Figure 33. Deformation in Traffic Lane, Item 2, After 200 Coverages

Figure 34. Item 2 After 400 Coverages

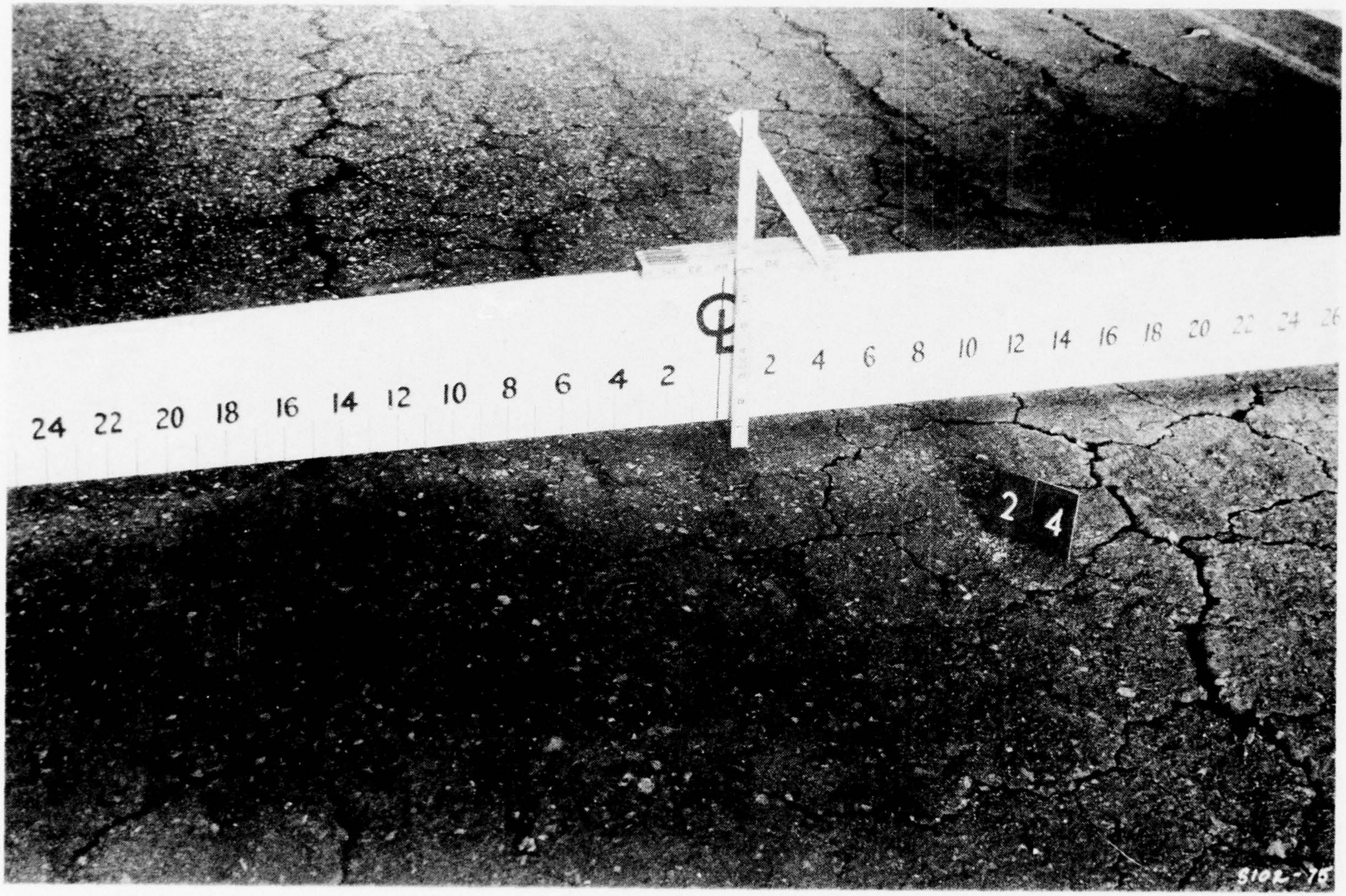


Figure 35. Deformation in Traffic Lane, Item 2, After 400 Coverages

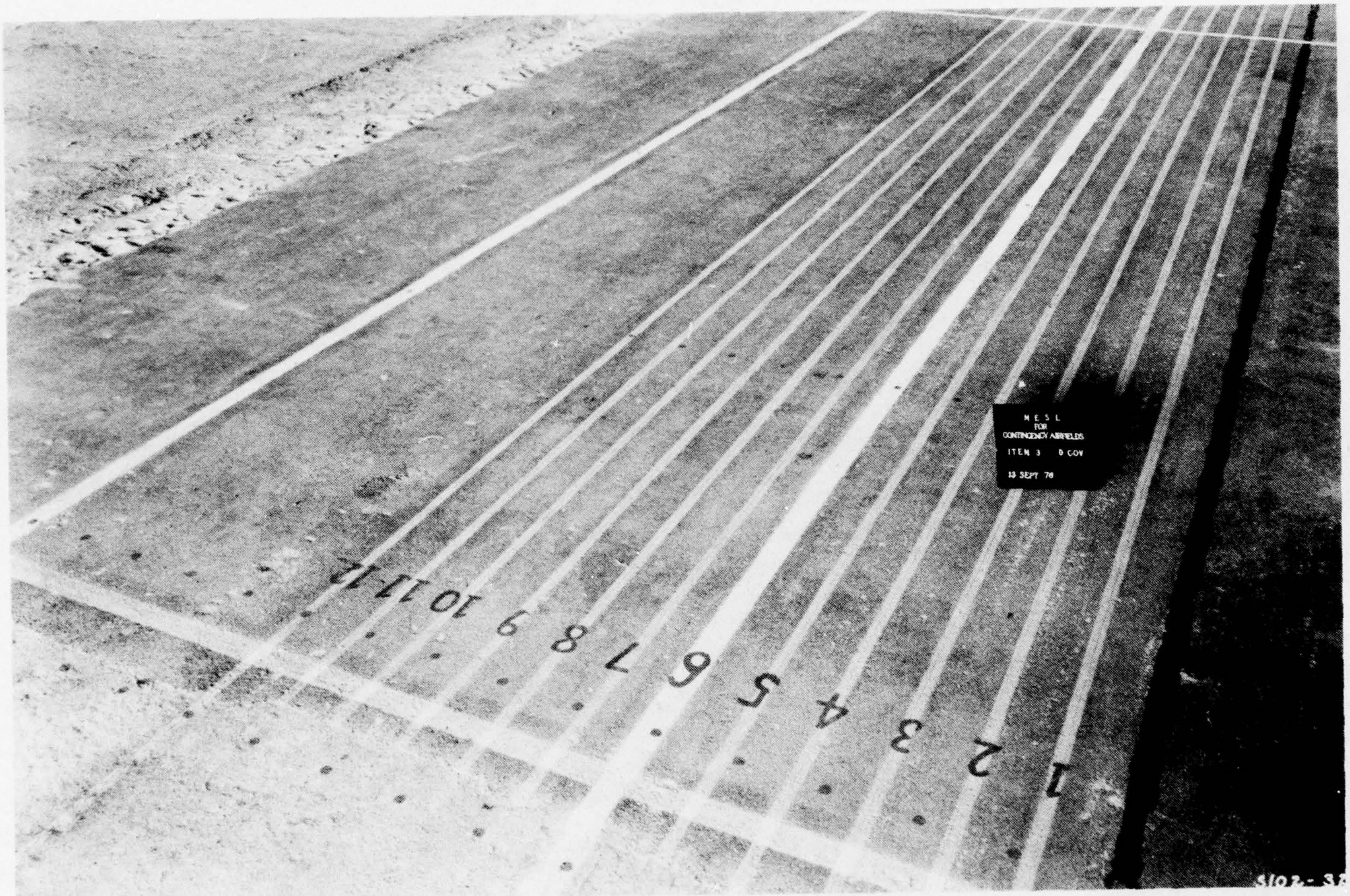


Figure 36. Item 3 Prior to Traffic

Figure 37. Item 3 After 10 Coverages

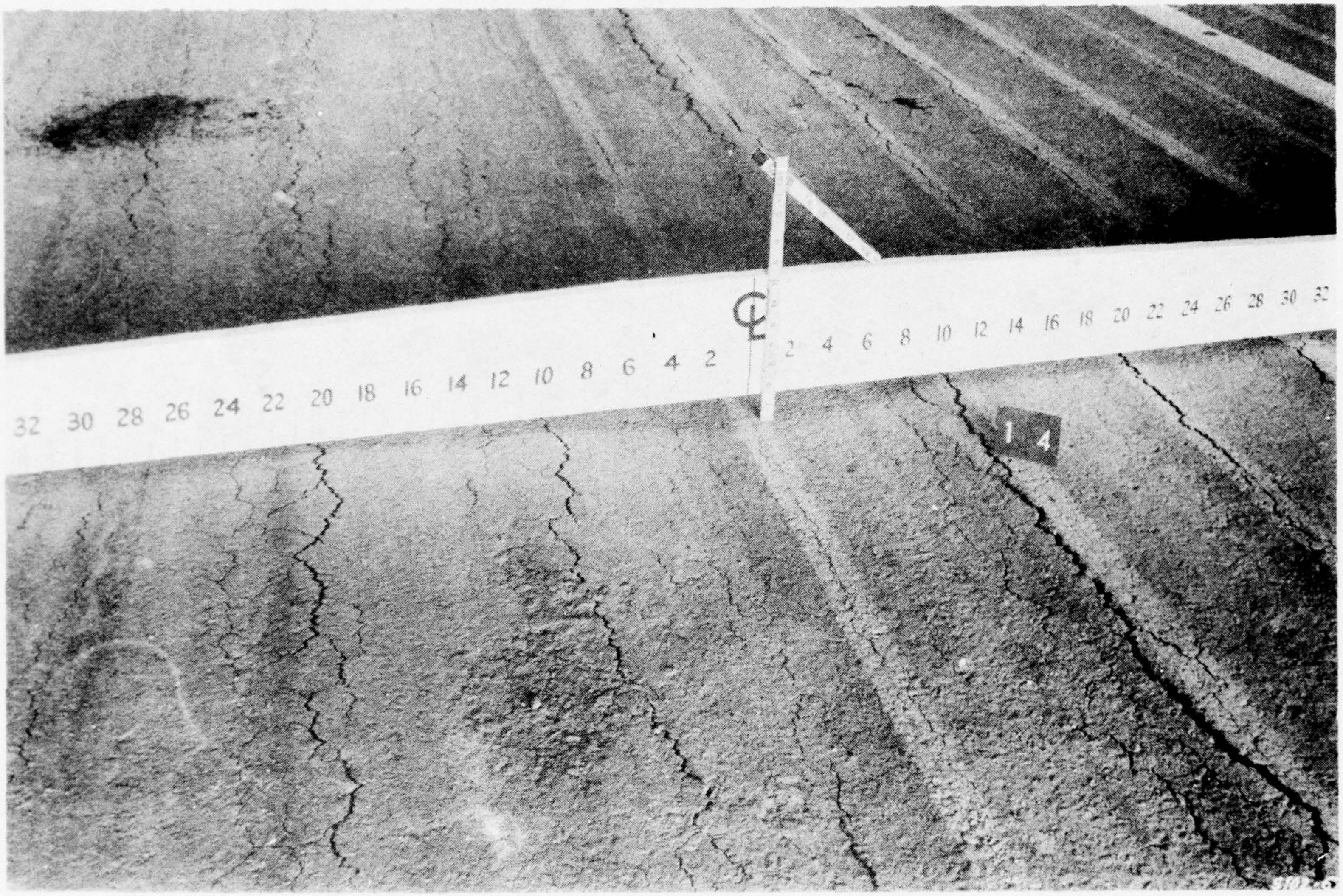


Figure 38. Deformation in Traffic Lane, Item 3, After 10 Coverages

Figure 39. Item 3 After 25 Coverages

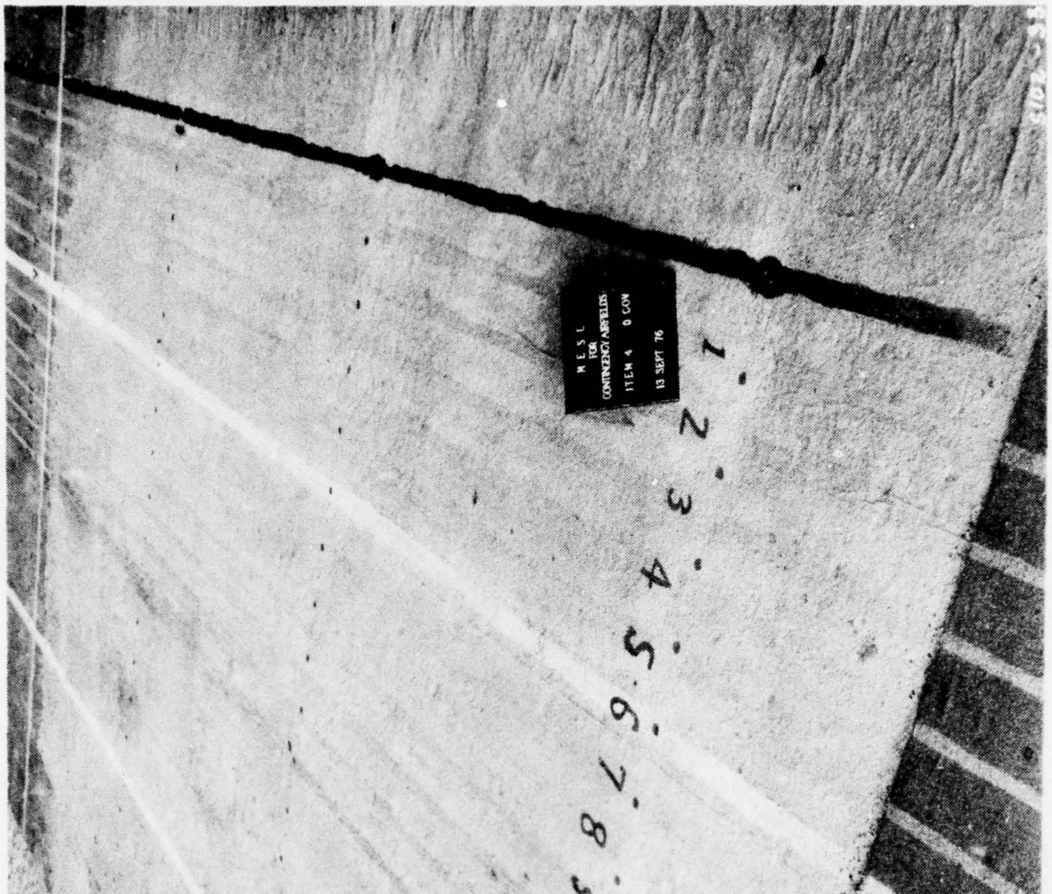


Figure 40. Item 4 Prior to Traffic

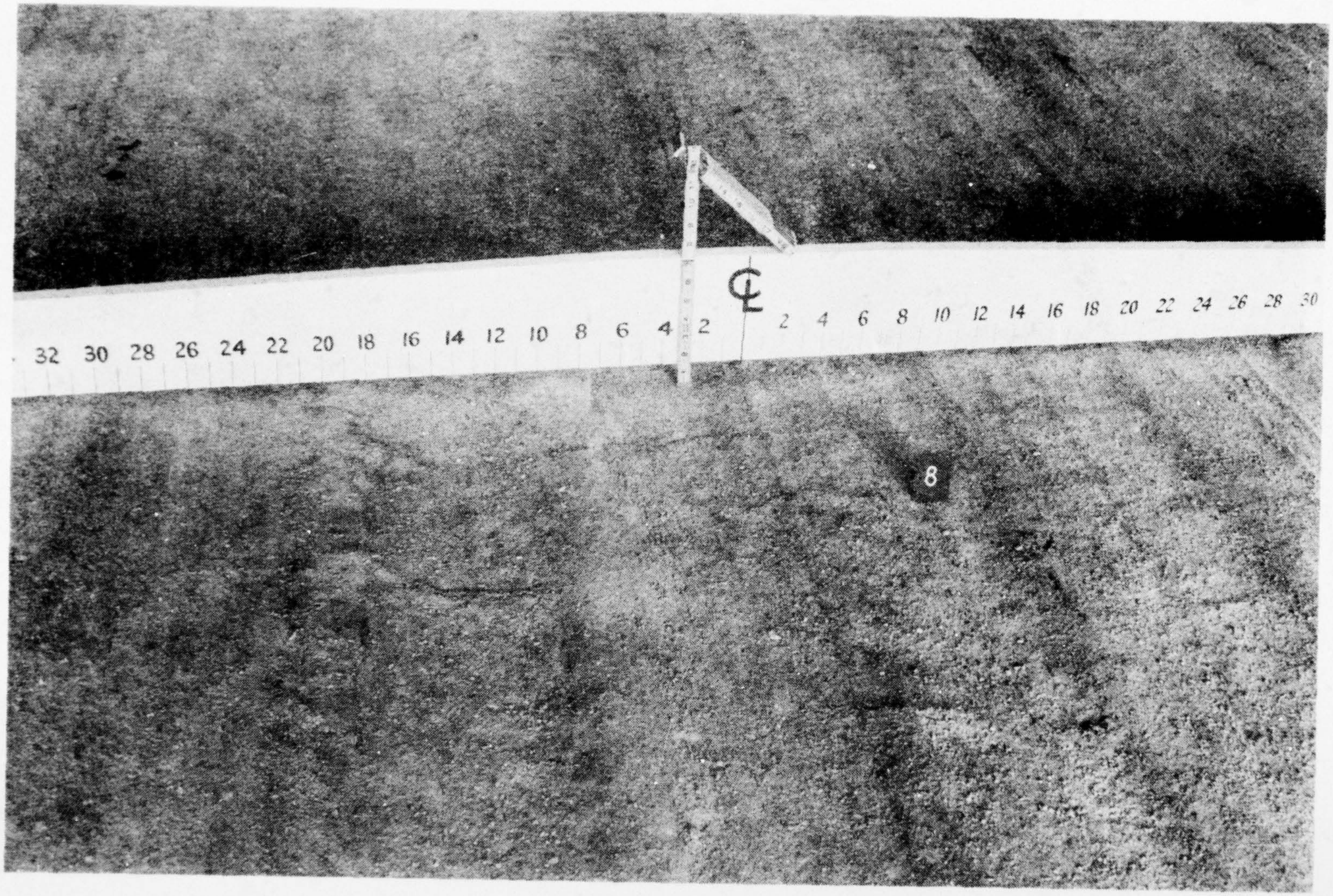


Figure 41. Deformation in Traffic Lane, Item 4, After 2 Coverages

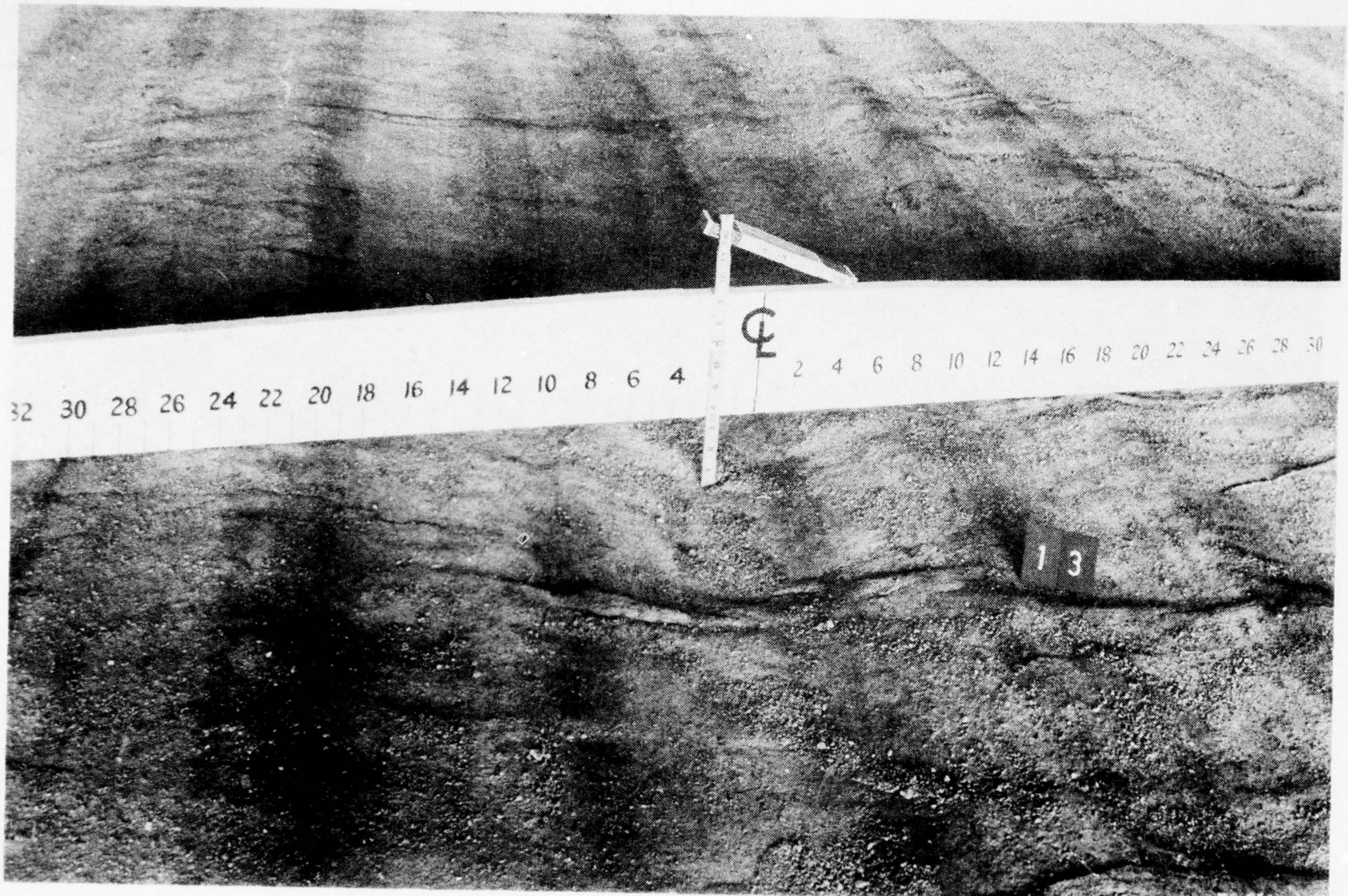


Figure 42. Deformation in Traffic Lane, Item 4, After 10 Coverages

Figure 43. Item 4 After 10 Coverages

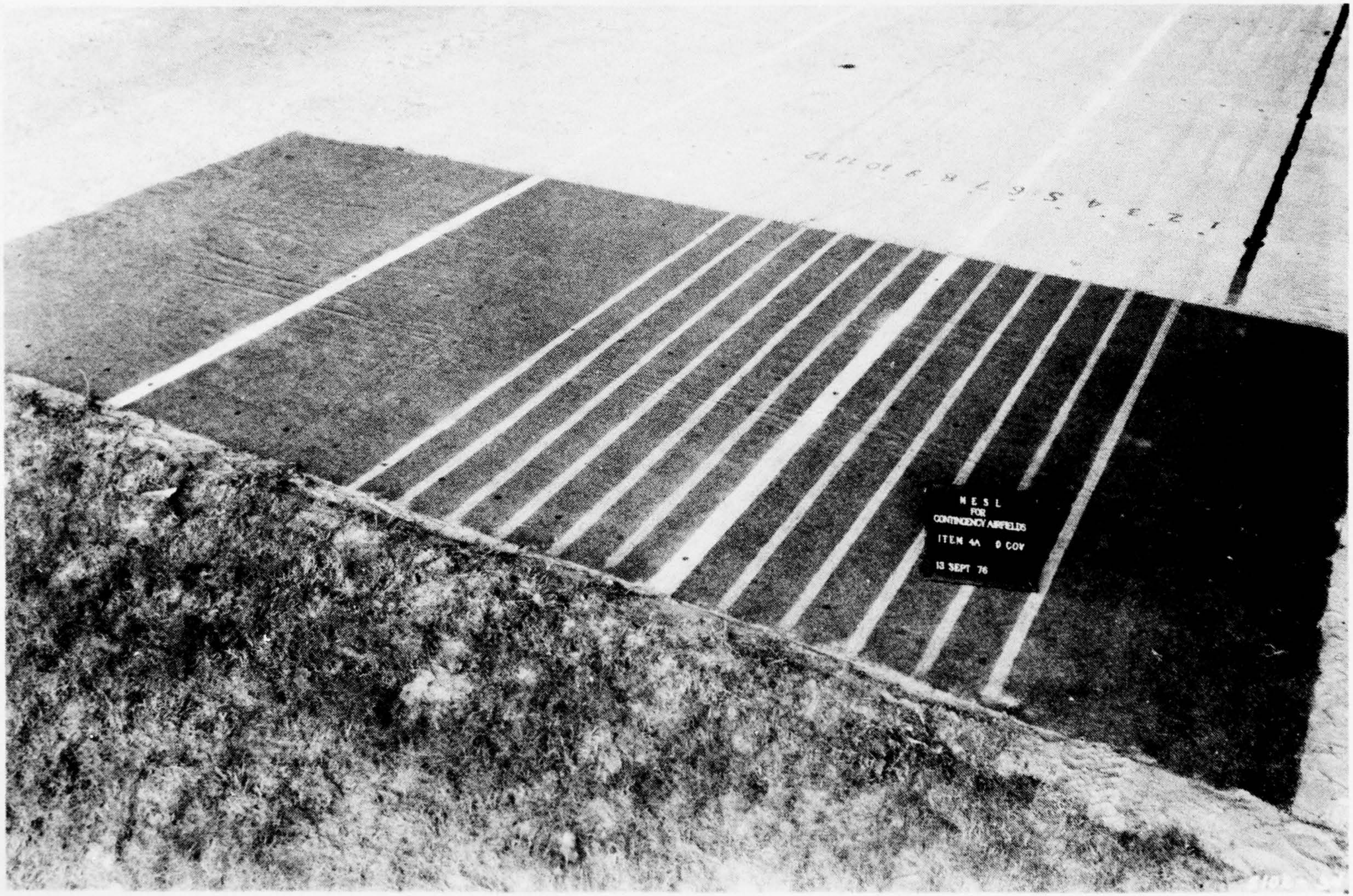


Figure 44. Item 4A Prior to Traffic

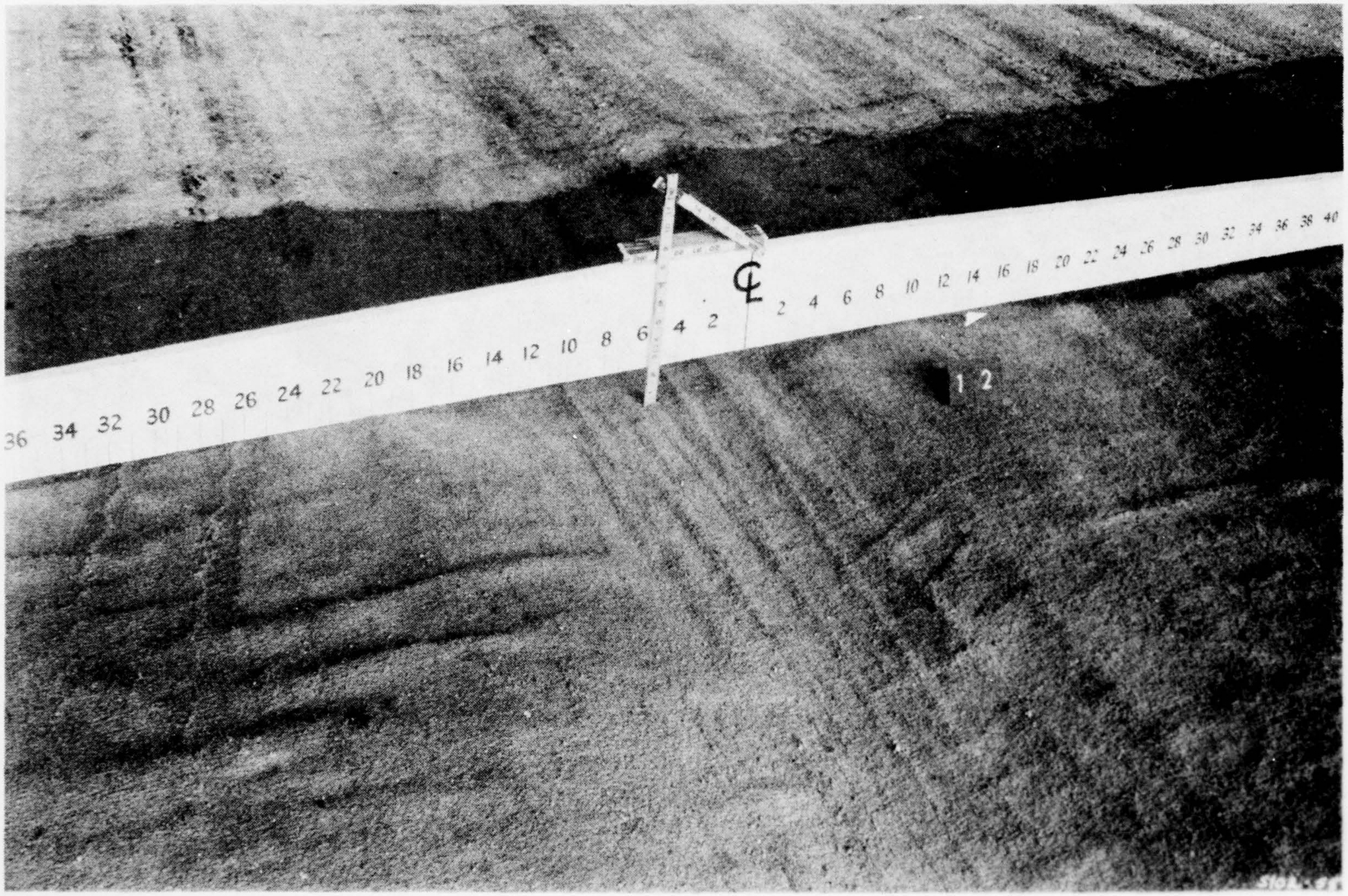


Figure 45. Deformation in Traffic Lane, Item 4A, After 10 Coverages

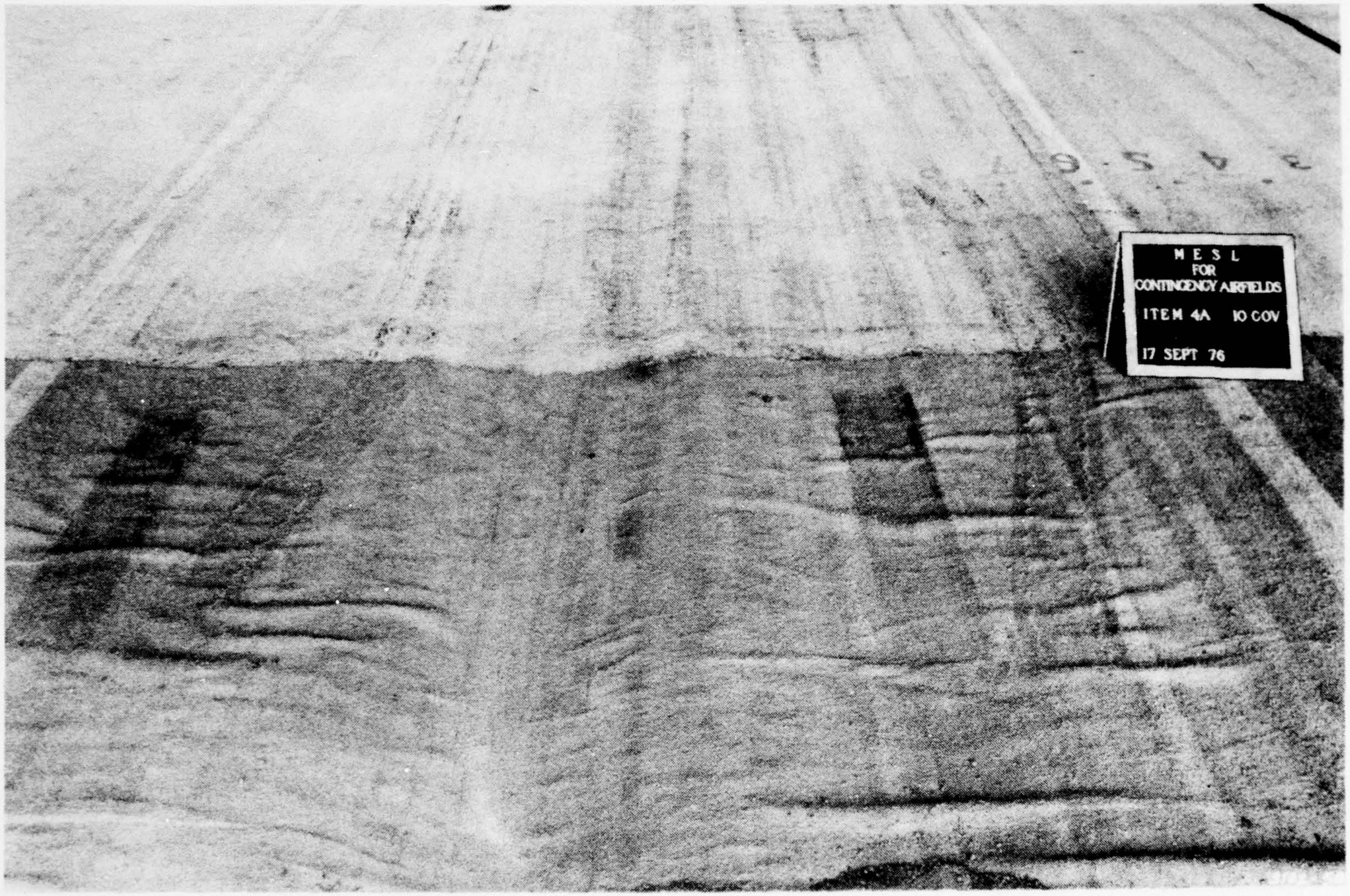


Figure 46. Item 4A After 10 Coverages

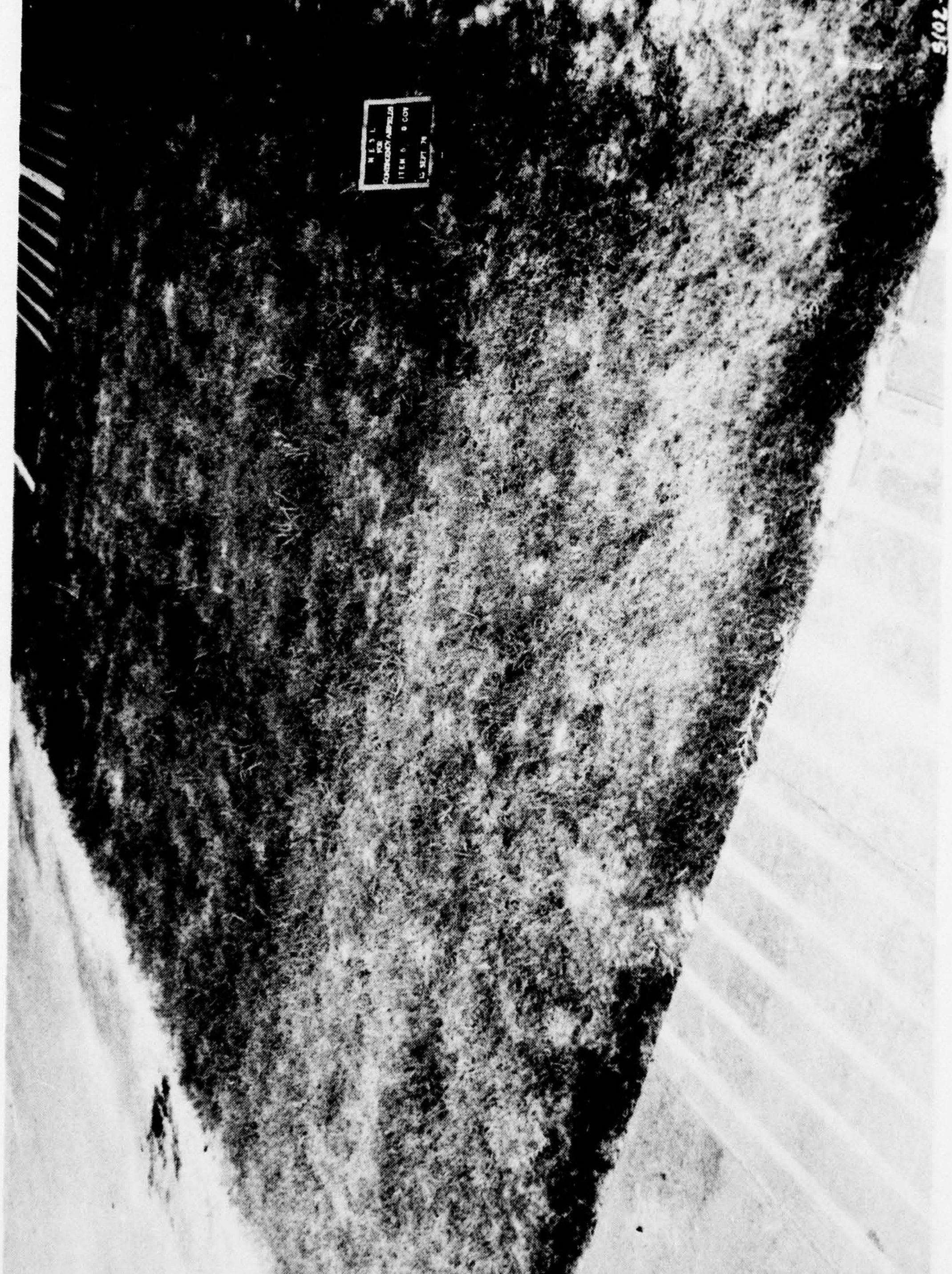


Figure 47. Item 5 Prior to Traffic

Figure 48. Rut in Item 5 After One Pass

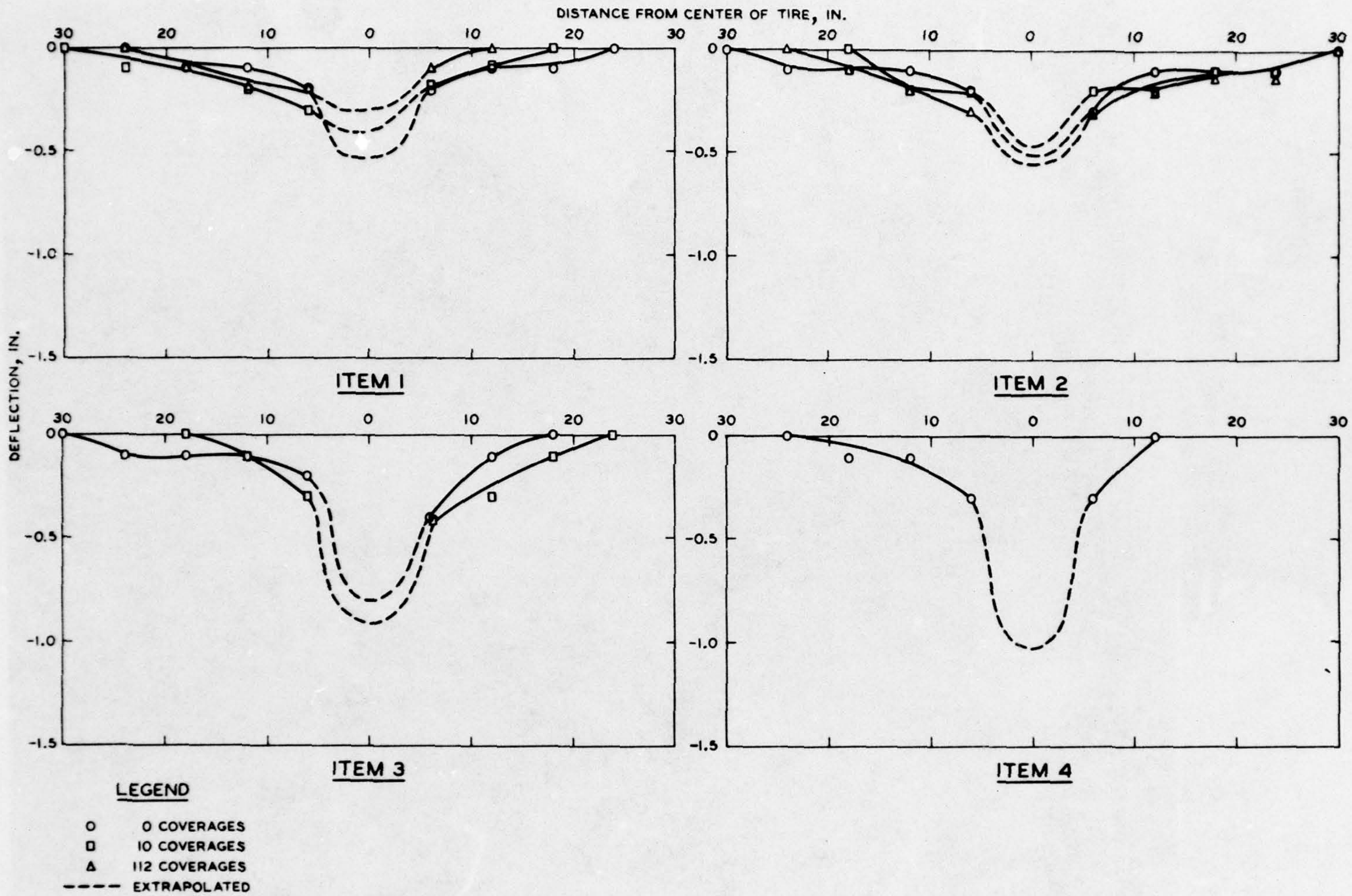


Figure 49. Comparative Deflections

Figure 50. Polyethylene Membrane on Bottom of MESL After Traffic, Item 1

Figure 51. Polyethylene Membrane on Bottom of MESL
After Traffic, Item 2

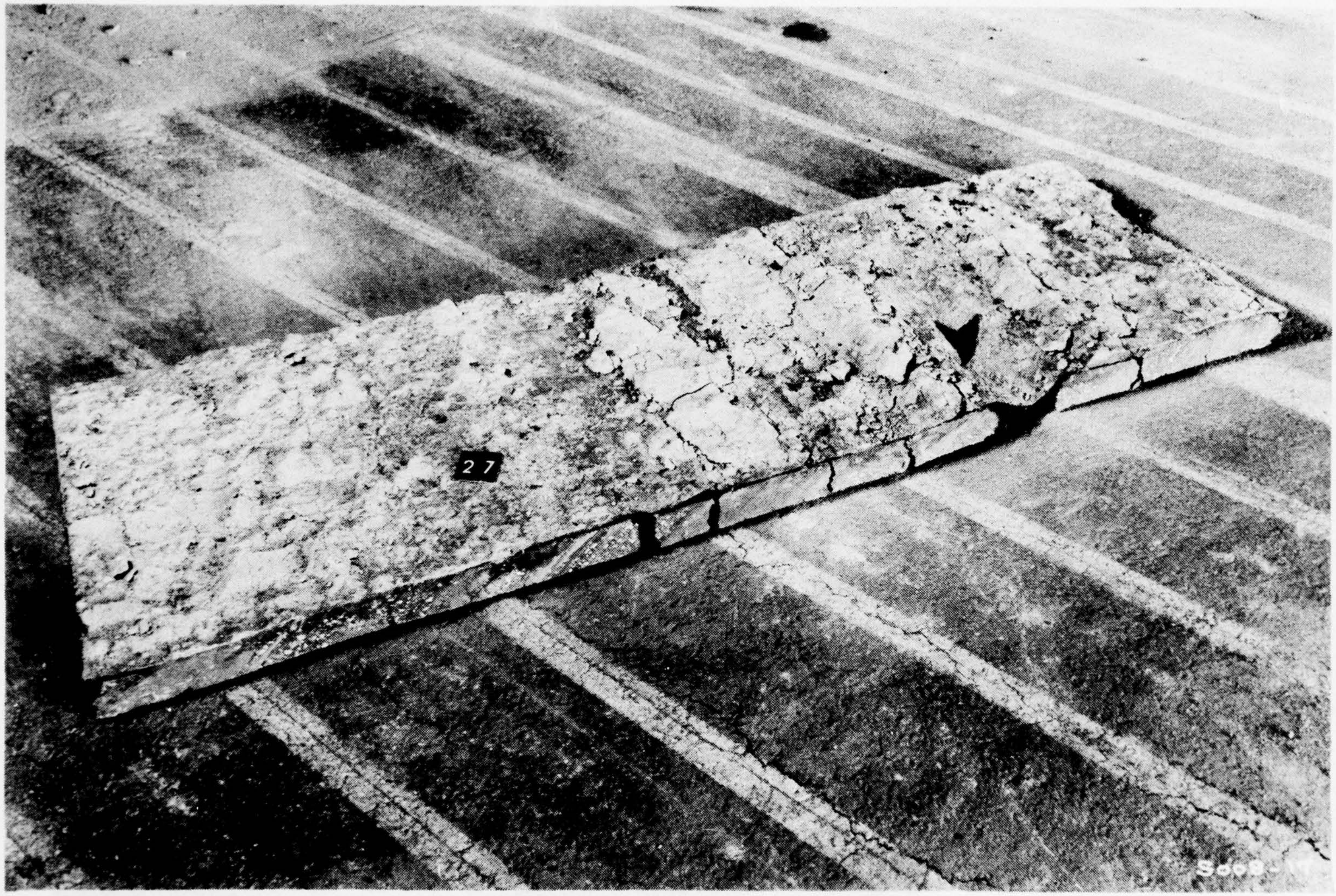


Figure 52. Wet Material That Adhered to Polypropylene Surface When Asphalt Concrete Slab Was Removed, Item 3

Figure 53. Polyethylene Membrane on Bottom of MESL After Traffic, Item 3

Figure 54. Rut in MESL, Item 5, After One Pass of Load Cart

TABLE 1. SUMMARY OF STABILITY, FLOW, VOIDS, AND DENSITY DATA FOR ASPHALTIC CONCRETE SPECIMENS

Test Item No.	Location	Asphalt Content % of Total Weight	Marshall Stability (lb)	Flow Units of 1/100 in.	Percent Voids Total Mix	Percent Voids Filled with Asphalt	Unit Weight Total Mix lb/cu ft	% Laboratory Density
	Plant-Mixed Laboratory Compacted Samples							
--	1st lift	4.8	1535	8	5.7	65.4	143.7	
--	2nd lift	4.8	1575	9	5.0	68.1	144.7	
	Field Cores (Before Traffic) Second Layer							
2	Left lane	4.8	--	--	7.6	57.8	140.8	97.3
2	Right lane	4.8	--	--	9.6	51.6	137.7	95.2
	Field Cores (After Traffic)							
1	In traffic lane	--	--	--	--	--	142.0	98.5[a]
1	Out of traffic lane	--	--	--	--	--	140.0	97.1[a]
2	In traffic lane	--	--	--	--	--	141.8	98.3[a]
2	Out of traffic lane	--	--	--	--	--	139.5	96.7[a]
3	In traffic lane	--	--	--	--	--	136.1	94.7
3	Out of traffic lane	--	--	--	--	--	140.3	97.6

a Laboratory density taken as average for the two lifts.

TABLE 2. SUMMARY OF CBR, WATER CONTENT, AND DRY DENSITY DATA

		As-Constructed				After Traffic					
Item	Material	Depth (in)	CBR	Moisture Content %	Density lb/cu ft	Depth (in)	CBR	Moisture Content %	Dry Density lb/cu ft	Total No. of Coverages	No. of Coverages at Failure
1	Lean clay	Surf	23	15.6	98.5	Surf	38	15.1	102.3	400	a
		6	20	15.6	97.3	6	31	15.4	101.7		
	Heavy clay	Surf	6.0	27.8	89.3	Surf	13	23.5	96.0		
		6	7.0	26.8	91.0	6	9.0	26.9	92.0		
		12	6.0	27.8	88.8	12	6.0	28.4	89.0		
2	Lean clay	Surf	21	15.6	98.5	Surf	33	15.5	104.3	400	400
	Heavy clay	Surf	7.0	27.1	89.0	Surf	9.0	23.8	95.5		
		6	6.0	27.7	89.0	6	8.0	27.2	88.5		
		12	7.0	27.5	88.8	12	8.0	27.3	89.4		
3	Lean clay	Surf	24	16.0	100.0	Surf	27	15.5	107.6	25	14
	Heavy clay	Surf	7.0	25.2	93.0	Surf	9.0	23.9	95.5		
		6	7.0	25.5	92.6	6	9.0	27.4	89.4		
		12	7.0	26.7	92.3	12	8.0	27.6	88.9		
4	Lean clay	Surf	20	16.0	99.7	Surf	29	16.1	107.2	14	10
		6	23	16.2	99.1	6	30	16.0	107.2		
	Heavy clay	Surf	6.0	27.3	89.3	Surf	7.0	25.4	92.8		
		6	6.0	24.8	93.5	6	7.0	27.5	90.3		
		12	5.0	28.6	88.4	12	7.0	27.7	90.0		
5	Lean clay	Surf	23	15.5	100.0	Surf	8	21.8	98.5	1 pass	1 pass
		6	23	15.6	98.3	6	11	21.1	98.8		
	Heavy clay	Surf	7.0	27.3	91.3	Surf	11	23.7	95.8		
		6	6.0	27.5	90.4	6	10	25.7	92.3		
		12	6.0	25.9	90.0	12	6.0	27.7	89.2		

a Traffic terminated at 400 coverages without failure.

TABLE 3. ROLLING WHEEL DRAWBAR PULL

Item	Force in lb Peak at Start	Rolling
1	1,600	900
2	2,400	900
3	2,500	1,300
4	3,200	1,700
4A	3,700	2,500
5	a	14,000

a Item failed.

INITIAL DISTRIBUTION

NGB/FSC/DE	1
HQ AFSC/DE	1
HQ AFSC/DLCAM	1
HQ USAFE/DE	11
TAC/DEE	1
AFLC/DEE	1
PACAF/DEE	1
ADCOM/DEE	1
USAF/PREM	1
USAF/PRE	1
USAF/DFCE	1
SAC/DE	2
AFRES/DE	1
AAC/DEE	1
MAC/DE	1
ATC/DE	1
AFIT/DEE	1
AFIT/DES	1
AFIT/Tech Lib	1
ASD/DEE	1
AFATL/DLODL	1
ADTC/DEE	1
Dir, USA Engr WW Exp Sta/WESSI	5
DDC	12
AUL	1
AFCEC/DEM	1
HQ USAFA/DFCE	1
CERL-FOM (Army)	1
Det 1 HQ ADTC/PRT	1
Det 1 HQ ADTC/CNO	8
Det 1 HQ ADTC/PRL	2
AFATL/DLODR	1

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